THE

REFRACTION OF THE EYE

A MANUAL FOR STUDENTS

BY

GUSTAVUS HARTRIDGE, F.R.C.S.

CONSULTING OPHTHALMIC SURGEON TO ST. BARTHOLOMEW'S HOSPITAL, CHATHAM;
ASSISTANT SURGEON TO THE ROYAL WESTMINSTER OPHTHALMIC HOSPITAL;
FORMERLY ASSISTANT SURGEON TO THE CENTRAL OPHTHALMIC
HOSPITAL AND CLINICAL ASSISTANT TO ROYAL
OPHTHALMIC HOSPITAL, MOORFIELDS

WITH NINETY-FOUR ILLUSTRATIONS

SECOND EDITION

LONDON
J. & A. CHURCHILL
11, NEW BURLINGTON STREET
1886

o.p.

May 9, 1899.
E.

PREFACE

TO THE

SECOND EDITION

The quick sale of the first edition has afforded me an early opportunity of making a few necessary corrections.

Some of the chapters have been partly rewritten and a few more woodcuts added; but the general plan of the book remains unaltered.

G. H.

December, 1885.

PREFACE

TO THE

FIRST EDITION

I HAVE endeavoured in the following pages to state briefly and clearly the main facts with which practitioners and students should be acquainted in order to enable them to diagnose errors of refraction accurately, and to prescribe suitable glasses for their correction.

Those who would do this with facility can only require the requisite amount of dexterity by practically working out a large number of cases of refraction. No book, nor even the knowledge gained by watching others who are thus employed, can take the place of this, the practical part of the subject.

To many of my readers the chapter on Optics may appear unnecessary. I have added it for the benefit of those whose school education did not include this subject, since its elementary details so completely underlie the whole subject of refraction, that every

student should understand them thoroughly before passing on to the real subject in hand.

I have found it necessary in several instances to repeat important matters, and this I have done to obviate the necessity of continual references to other parts of the book, as well as in some cases to impress the importance of the subject upon the student.

The woodcuts are numerous in proportion to the size of the work, but I consider that they are a very great help to the thorough understanding of the subject.

The old measurements have been purposely omitted in favour of the almost universally adopted metrical system. It is confusing to the learner to have to do with two distinct sets of measurements, and no possible good can accrue from perpetuating the old system of feet and inches.

At the end of the work I have given a list of those authors to whom I have been indebted for much valuable information; and, in conclusion, I take this opportunity of thanking my numerous friends for their help and suggestions.

G. H.

47, Kensington Park Gardens, W.;
January, 1884.

CONTENTS

CHAPTER I

CHAPTER II

CHAPTER III

CHAPTER IV

CHAPTER V

CHAPTER VI

CHAPTER VII

CHAPTER VIII

CHAPTER IX

CHAPTER X

CHAPTER XI

LIST OF ILLUSTRATIONS

THE REFRACTION OF THE EYE

CHAPTER I

OPTICS

Rays of light coming from any distant source, although actually slightly divergent, are assumed to be parallel.

The amount of divergence of rays is proportionate to the distance of the point from which they come.

A ray of light meeting with a body, may be absorbed, reflected, or if it is able to pass through this body, it may be refracted.

Reflection takes place from any polished surface and according to two laws.

1st.—The angle of reflection is equal to the angle of incidence.

2nd.—The reflected and incident rays are both in the same plane, which is perpendicular to the reflecting surface.

Thus if A B be the ray incident at B on the mirror C D, and B E the ray reflected, the perpendicular P B, will

divide the angle A B E into two equal parts, the angle A B P is equal to the angle P B E; and A B, P B and E B lie in the same plane.

FIG. 1.

When reflection takes place from a plane surface, the image is projected backwards to a distance behind the mirror, equal to the distance of the object in front of it, the image being of the same size as the object.

FIG. 2.

M. The mirror. C. The candle. C′. The virtual image of the candle. E. The eye of the observer receiving rays from mirror.

Thus in Fig. 2 the image of the candle C, is formed behind the mirror M at C′, a distance behind the mirror, equal to the distance of the candle in front of it, and an observer's eye placed at E, would receive the rays from C as if they came from C′.

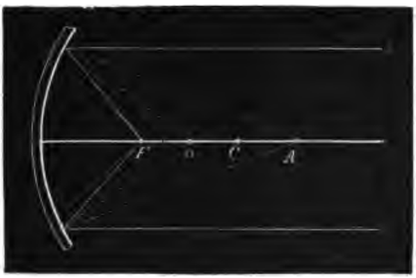
The image of the candle so formed by a plane mirror is called a *virtual image.*

Reflection from a Concave Surface

A concave surface may be looked upon as made up of a number of planes inclined to each other.

Parallel rays falling on a concave mirror are reflected as convergent rays, which meet on the axis at a point (F, Fig 3) called the *principal focus,* about

FIG. 3.



equally distant from the mirror and its centre C. The distance of the principal focus from the mirror is called the focal length of the mirror.

If the luminous point be situated at F, then the diverging rays would be reflected as parallel to each other and to the axis.

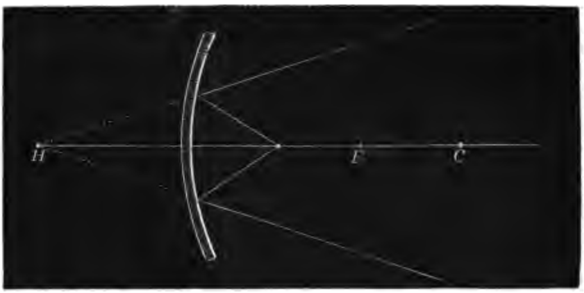
If the point is at the centre of the concavity of the mirror (C), the rays return along the same lines, so that the point is its own image.

If the point be at A the focus will be at *a*, and it will be obvious that if the point be moved to *a*, its focus will be at A; these two points therefore, A and *a*, bear a reciprocal relation to each other and are called *conjugate foci*.

If the luminous point is beyond the centre, its conjugate focus is between the principal focus and the centre.

If the luminous point is between the principal focus and the centre, then its conjugate is beyond the centre; so that the nearer the luminous point approaches the principal focus, the greater is the distance at which the reflected rays meet.

FIG. 4.



If the point be nearer the mirror than F the principal focus, the rays will be reflected as divergent and will therefore never meet; if, however, we continue these diverging rays backwards, they will unite at a point

(H) behind the mirror; this point is called the *virtual focus*, and an observer situated in the path of reflected rays will receive them as if they came from this point.

Thus it follows that—

Concave mirrors produce two kinds of images or none at all, according to the distance of the object, as may be seen by looking at oneself in a concave mirror; at a certain distance one sees a small and inverted image, at a less distance the image is confused and disappears when at the focus; still nearer, the image is erect and larger, being then a virtual image.

Reflection from a Convex Surface

Parallel rays falling on such a surface become divergent, hence never meet, but if the diverging rays thus formed are carried backwards by lines, then an imaginary image is formed which is called *negative*, and at a point called the *principal focus* (F).

FIG. 5.

Foci of convex mirrors are virtual; and the image, whatever the position of the object, is always virtual, erect, and smaller than the object.

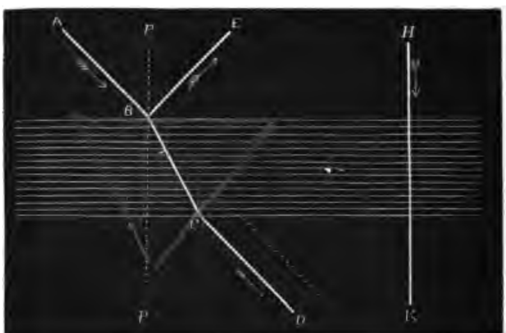
The radius of the mirror is double the principal focus.

Refraction.—A ray of light passing through a transparent medium into another of a different density is refracted, unless the ray fall perpendicular to the surface separating the two media, when it continues its course without undergoing any refraction (Fig. 6, H K).

A ray passing from a rarer to a denser medium is refracted towards the perpendicular; as shown in Fig. 6, the ray A B is refracted at B, towards the perpendicular P P.

In passing from the denser to the rarer medium the ray is refracted from the perpendicular, B D is refracted at C from P P (Fig. 6).

FIG. 6.



Reflection accompanies refraction, the ray dividing itself at the point of incidence into a refracted portion B C and a reflected portion B E.

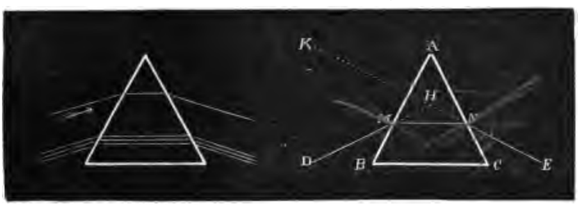
The amount of refraction is the same for any medium at the same obliquity and is called the index of refraction; air is taken as the standard and is called 1; the index of refraction of water is 1·3, that of glass 1·5. The diamond has almost the highest refractive power of any transparent substance and has an index of refraction of 2·4.

The refractive power of a transparent substance is not always in proportion to its density.

If the sides of the medium are parallel, then all rays, except those perpendicular to the surface which pass through without altering their course, are refracted twice, as at B and C (Fig. 6), and continue in the same direction after leaving as before entering.

If the two sides of the refracting medium are not parallel, as in a prism, the rays cannot be perpendicular to more than one surface at a time.

FIG. 7. FIG. 8.



Therefore every ray falling on a prism must undergo refraction, and the deviation is always towards the base of the prism.

The relative direction of the rays is unaltered (Fig. 7).

If D M (Fig. 8) be a ray falling on a prism (A B C) at M, it is bent towards the base of the prism, assuming the direction M N; on emergence it is again bent at N, an observer placed at E would receive the ray as if it came from K; the angle K H D formed by the two lines at H is called the *angle of deviation*, and is about half the size of the *principal angle* formed at A by the two sides of the prism.

Refraction by lenses is somewhat more complicated.

A lens is an optical contrivance usually made of glass, and consists of a refracting medium with two opposite surfaces, one or both of which may be

FIG. 9.

segments of a sphere, they are then called spherical lenses, of which there are six varieties.

1. Plano-convex, the segment of one sphere (Fig. 9, B).
2. Biconvex, segments of two spheres (Fig. 9, A).
3. Converging concavo-convex, also called a converging meniscus.
4. Plano-concave.
5. Biconcave.

6. Diverging concavo-convex, called also a diverging meniscus.

FIG. 10.

1 2 3 4 5 6

Lenses may be looked upon as made up of a number of prisms with different refracting angles—convex lenses, of prisms placed with their bases together; concave lenses, of prisms with their edges together.

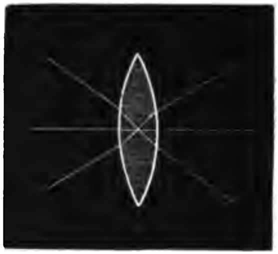
A ray passing from a less refracting medium (as air) through a lens, is deviated towards the thickest part, therefore the three first lenses, which are thickest at the centre, are called *converging*, and the others, which are thickest at the borders, *diverging*.

A line passing through the centre of the lens (called the *optical centre*) at right angles to the surfaces of the lens, is termed the *principal axis*, and any ray passing through that axis is not refracted.

All other rays undergo more or less refraction.

Rays passing through the optical centre of a lens, but not through the principal axis, emerge in the same direction as they entered; the deviation in thin lenses is so slight that they are usually assumed to pass through in a straight line, and are called *secondary axes* (Fig. 11).

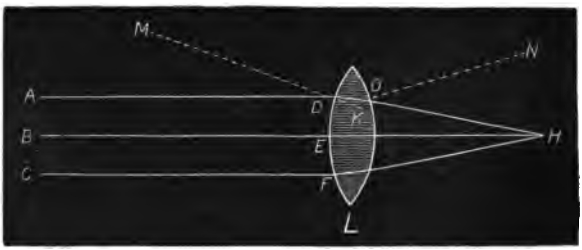
FIG. 11.



Lens with secondary axes undergoing slight deviation.

Parallel rays falling on a biconvex lens are rendered convergent; thus, in Fig. 12 the rays A, B, C, strike the surface of the lens (L) at the points D, E, F; the centre ray (B) falls on the lens at E perpendicular to its surface, and therefore passes through in a straight line; it also

FIG. 12.

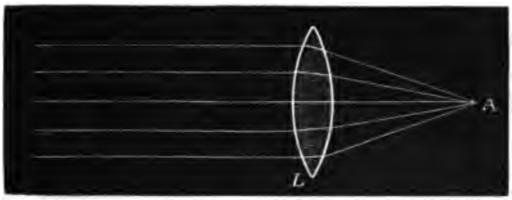


emerges from the lens at right angles to its opposite surface, and so continues its course without deviation; but the ray (A) strikes the surface of the lens obliquely at D, and as the ray is passing from one medium (air) to another (glass) which is of greater density, it is bent towards the perpendicular of the surface of the lens,

shown by the dotted line M, K; the ray after deviation, passes through the lens striking its opposite surface obliquely at O, and as it leaves the lens, enters the rarer medium (air), being deflected from the perpendicular N, O; it is now directed to H, where it meets the central ray B H; ray C, after undergoing similar refractions meets the other rays at H, and so also all parallel rays falling on the biconvex lens (L).

Parallel rays, therefore, passing through a convex lens (L) are brought to a focus at a certain fixed point (A) beyond the lens; this point is called the *principal focus,* and the distance of this focus from the lens is called the focal length of the lens.

FIG. 13.

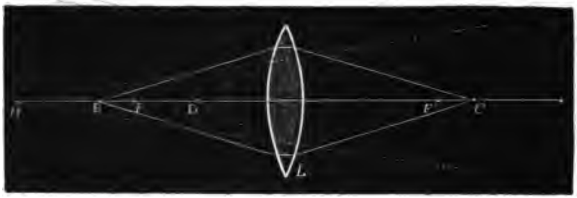


Rays from a luminous point placed at the principal focus (A) emerge as parallel after passing through the lens.

Divergent rays from a point (B) outside the principal focus (F, Fig. 14) meet at a distance beyond (F′) the principal focus on the other side of the lens (L), and if the distance of the luminous point (B) is equal to twice the focal length of the lens, the rays will focus at a point (C) the same distance on the opposite side of

the lens (L), rays coming from C would also focus at B, they are therefore called conjugate foci, for we can

FIG. 14.



indifferently replace the image (C) by the object (B) and the object (B) by the image (C)

If the luminous point (D) be between the lens and the principal focus (F), then the rays will issue from the lens divergent, though less so than before entering; and if we prolong them backwards they will meet at a point (H) further from the lens than the point D; H will therefore be the virtual focus of D, and the conjugate focus of D may be spoken of as negative.

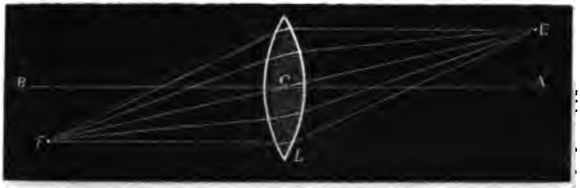
Biconvex lenses have therefore two principal foci, F and F′, one on either side, at an equal distance from the centre.

In ordinary lenses, and those in which the radii of the two surfaces are nearly equal, the principal focus closely coincides with the centre of curvature.

We have assumed the luminous point to be situated on the principal axis, supposing, however, it be to one side of it as at E (Fig 15), then the line (E F) passing through the optical centre (C) of the lens (L) is a secondary axis, and the focus of the point E will be

found somewhere on this line, say at F, so that what has been said respecting the focus of a luminous point

FIG. 15.



on the principal axis (A B), is equally true for points on a secondary axis, provided always that the inclination of this secondary axis is not too great, when the focus would become imperfect from much spherical aberration.

In biconcave lenses the foci are always virtual whatever the distance of the object.

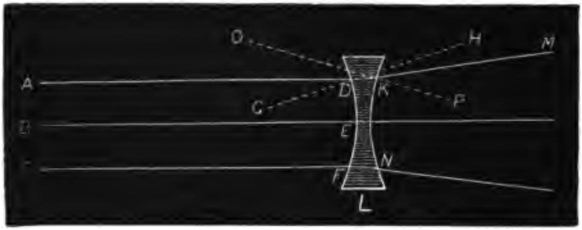
FIG. 16.

Rays of light parallel to the axis, diverge after refraction, and if their direction be continued backward, they meet at a point termed the principal focus (F).

Fig. 17 shows the refraction of parallel rays by a

biconcave lens (L); the centre ray B, strikes the lens at E perpendicular to its surface, passing through without refraction and as it emerges from the opposite side of the lens perpendicular to its surface, it continues

FIG. 17.

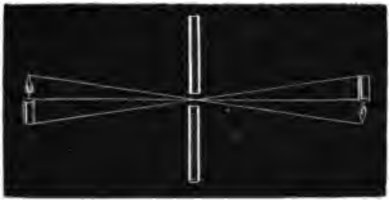


in a straight line; the ray A strikes the lens obliquely at D and is refracted towards the perpendicular, shown by the dotted line G, H, the ray after deviation passes through the lens to K, where, on entering the medium of less density obliquely, it is refracted from the perpendicular O, P, in the direction K, M, the same takes place with ray C, at F and N, so also with all intermediate parallel rays.

Formation of images.—To illustrate the formation of images the following simple experiment may be carried out: place on one side of a screen, having a small perforation, a candle, and on the other side a sheet of white cardboard at some distance from the object, to receive the image formed; rays diverge from the candle in all directions, most of those falling on the screen are intercepted by it, but some few rays pass through the perforation and form an image of the

candle on the cardboard, the image being inverted because the rays cross each other at the orifice; it can further be shown that when the candle and card-

FIG. 18.



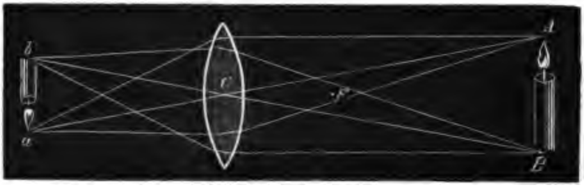
board are equally distant from the perforated screen, the candle flame and its image will be of the same size. If the cardboard be moved further from the perforation the image is enlarged, if it be moved nearer it is diminished; if we make a dozen more perforations in the screen, a dozen more images will be formed on the cardboard, if a hundred then a hundred, but if the apertures come so close together that the images overlap, then instead of so many distinct images we get a general illumination of the cardboard.

The image of an object is the collection of the foci of its several points, the images formed by lenses are, as in the case of the foci, real or virtual. Images formed therefore by convex lenses may be real or virtual.

In Figure 19, let A B be a candle situated at an infinite distance, from the extremities of A B, draw two lines passing through the optical centre (c) of a biconvex lens, the image of A will be formed somewhere on this line (termed a secondary axis), say at *a*,

rays from B at *b*, so *b a* is a small inverted image of the candle A B, formed at the principal focus of the convex lens. Had the candle been placed at twice the

Fig. 19.



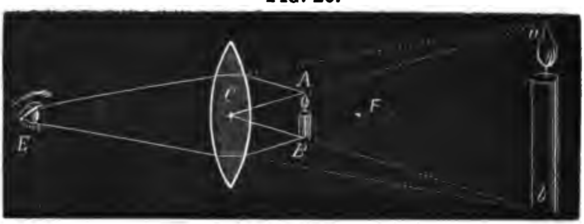
Real inverted image formed by convex lens.

focal distance of the lens, then its image would be formed at the same point on the opposite side of the lens, of the same size as the object, and inverted.

If the candle be at the principal focus (F) then the image is at an infinite distance, the rays after refraction being parallel.

If, however, the candle (A B) be nearer the lens than

Fig. 20.



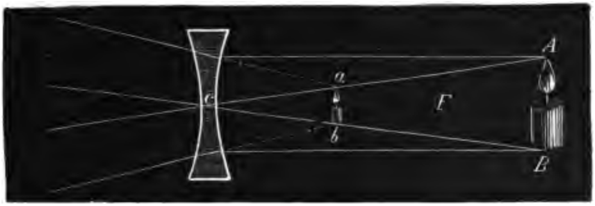
Virtual image formed by convex lens.

the focus, then the rays which diverge from the candle, will, after passing through the convex lens, be still

divergent so that no image is formed; an eye placed at E would receive the rays from A B as if they came from *a b; a b* is therefore a virtual image of A B, erect and larger than the object, and formed on the same side of the lens as the object.

Images formed by bi-concave lenses are always virtual, erect, and smaller than the object; let A B be

FIG. 21.



Virtual image formed by concave lens.

a candle, and F the principal focus of a biconcave lens, draw from A B two lines through C, the optical centre of lens, and lines also from A and B parallel to the axis, after passing through the lens they diverge and have the appearance of coming from *a b*, which is therefore the virtual image of A B.

A real image can be projected on to a screen, but a virtual one can only be seen by looking through the lens.

CHAPTER II

REFRACTION. ACCOMMODATION. CONVERGENCE

THE eye may be looked upon as an optical instrument, a sort of photographic camera, designed to produce by means of its refracting system a small and inverted picture of surrounding objects upon the retina; the stimulation thus produced by the picture is conducted by the optic nerve to the brain, which must be able to interpret correctly the impressions transmitted to it. Immediately behind the transparent retina is a layer of pigment, which absorbs the rays of light as soon as the image is formed; were this not so the rays would be reflected to other parts of the retina, and cause much dazzling, interfering considerably with vision, as in the case of albinos. The refracting system of the eye is so arranged that but little, if any, spherical or chromatic aberration takes place, as is the case with ordinary optical instruments.

For distinct and accurate vision the following conditions are necessary:—

1st. That a well-defined inverted image be formed on the layer of rods and cones at the yellow spot.

2nd. That the impression there received be conveyed to the brain.

In a work of this character the first of these conditions alone concerns us, and for the carrying out of this—the media being transparent—three important factors call for a separate description, viz. :—

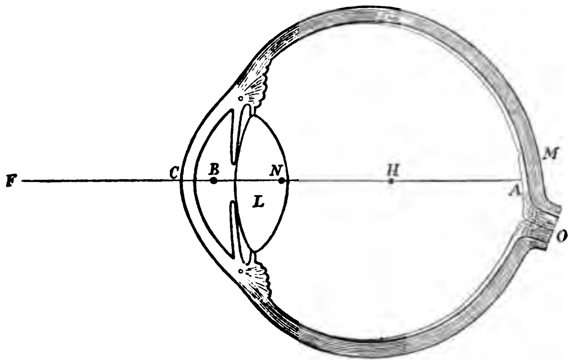
Refraction.
Accommodation.
Convergence.

Refraction.—This term is used to express the optical condition of the eye in a state of rest. There are three refracting surfaces in the eye—the anterior surface of the cornea, the anterior surface of the lens, and the anterior surface of the vitreous; and three refracting media, the aqueous, the lens, and the vitreous. These together make up the dioptric system, and may for the sake of simplicity be looked upon as forming a convex lens of about 23 mm. focus. What was said about convex lenses applies equally to the eye as an optical instrument.

A ray of light falling on the cornea does not, however, follow the simple direction we might imagine when considering the eye merely as a lens of 23 mm. focus, but it must be looked upon as a compound system, composed of a spherical surface and a biconvex lens. To enable us to understand the course of a ray through the eye, it is necessary to be acquainted with the cardinal points of this compound system; too much space would be occupied to explain how the position of these points is arrived at, but it suffices to say, that having first found the cardinal points of the cornea and then those of the lens, the cardinal points

of the eye will be the result of these two systems together. In the following diagram of the emmetropic eye the cardinal points of this compound

FIG. 22.



system are shown, all situated on the optic axis (F A); at B are two principal focal points, situated so closely together in the anterior chamber, that they may conveniently be looked upon as one point. At N are two nodal points, also close together; for simplicity we shall consider them as one point, we then have the following: C, the cornea; L, the lens; M, the macula; O, the optic nerve; F A, the optic axis; B, the principal focal point, 2 mm. behind the cornea; N, the nodal point just in front of the posterior surface of the lens, 7 mm. behind the cornea; H, the centre of rotation of the eye, 9·2 mm. in front of the retina. Rays parallel before falling on the cornea come to a focus on the retina 22·8 mm. behind the cornea. Rays

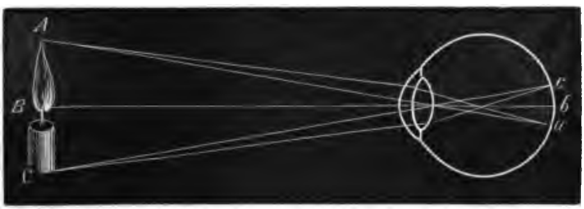
parallel in the vitreous, focus at the anterior focal point F situated 13·7 mm. in front of the cornea.

The *nodal point* corresponds nearly to the optical centre, the axis ray passing through this point is not refracted, all other rays passing through it form secondary axes.

Fig. 19 shows that an image formed by a biconvex lens is an inverted one; so also is that formed by the refracting surfaces of the eye, as can easily be proved by the following figure, and it is essential that the method of formation of these inverted images be thoroughly understood.

From every point of an object A B C, proceed divergent rays. Some of those coming from A pass through the pupil, and being refracted by the dioptric system, come to a focus on the retina at *a*: some coming

FIG. 23.



from B focus at *b*, and some from C at *c*. In the same way rays come from every point of the object as divergent rays, and are brought to a focus on the retina; so that the retina being exactly at the focal distance of the refracting system, receives a well-defined inverted image.

Much has been said and written as to why images

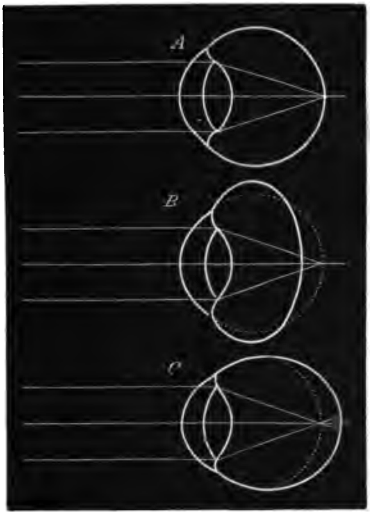
which are formed in an inverted position on the retina should be seen upright, and all sorts of ingenious explanations have from time to time been given. It is entirely a matter of education and experience, which is supplemented and corroborated by the sense of touch. We have no direct cognisance of the image on the retina, nor of the position of its different parts, but only of the stimulation of the retina produced by the image, which stimulation is conducted by the optic nerve to the brain, producing there certain molecular changes. We do not actually see the retinal image, but the object from which the rays emanate, and we refer the sensation in their direction; thus, if an image is formed on the upper part of our retina, we refer the sensation downwards from which the rays must have come.

The refraction of the eye is said to be normal, when parallel rays are united exactly on the layer of rods and cones of the retina; in other words, when the retina is situated exactly at the principal focal distance of the refracting system of the eye. This condition is called *emmetropia* (Εμ, within, *μέτρον*, measure, *ὤψ*, the eye). If parallel rays are focussed behind, or in front of the retina, the term *ametropia* (*a*, priv., *μέτρον*, measure, *ὤψ*, the eye) is used, and of this there are two opposite varieties.—

Hypermetropia, when the eyeball is so short, that parallel rays are brought to a focus behind the retina (Fig. 24, B).

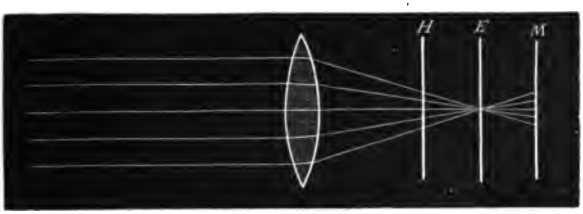
Myopia, when the eyeball is too long, so that parallel rays focus in front of the retina (Fig. 24, C).

FIG. 24.



A. Emmetropic eye. B. Hypermetropic eye. C. Myopic eye.

FIG. 25.



Convex lens of 23 mm. focus. Parallel rays focus at E (emmetropia) on the screen, forming a well-defined image of object from which rays come; at H (hypermetropia) forming a diffusion patch instead of an image. M (myopia), also a diffusion patch, the rays having crossed and become divergent.

Emmetropia in a strict mathematical sense is very rare.

If we represent the eye by a biconvex lens and the retina by a screen, emmetropic when situated at the principal focus of the lens as E Fig. 25, we make it hypermetropic (H) by bringing forward the screen, and myopic (M) by moving it further away from the lens.

In all eyes, vision ranges from the far point, (which in the emmetropic eye is at infinity), to the near point.

The near point (punctum proximum) varies in the normal eye. It recedes as age advances, but should not be further off than 22 cm. (Page 164).

Infinity is any distance beyond 6 metres, the rays coming from a point at or beyond that distance being parallel, or almost so.

The emmetropic eye, therefore, is one whose far point, or punctum remotum, is situated at infinity. The hypermetropic eye has its punctum remotum beyond infinity, and the myopic at a finite distance.

When the near point has receded beyond 22 cm. (which usually occurs in the emmetropic eye about the age of forty-five), the eye is said to be *presbyopic.*

Generally the two eyes are similar in their refraction, though sometimes there is a very great difference. One may be hypermetropic, the other myopic; or one emmetropic, the other ametropic. *Anisometropia* is the term used when the two eyes thus vary in their refraction.

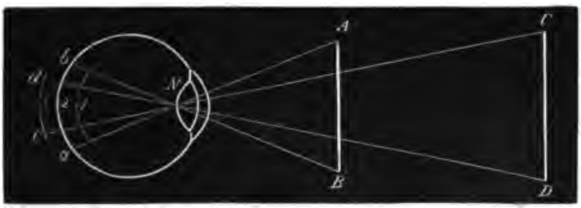
There may be differences also between the refraction

in the different meridians of the same eye—*astigmatism.*

In all forms of ametropia the acuteness of vision is liable to be diminished. The visual acuteness also decreases slightly as age advances, without any disease.

The acuteness refers always to central vision. The yellow spot is the most sensitive part of the retina, and the sensibility diminishes rapidly towards the periphery. The acuteness is measured by the size of the visual angle, that is, the angle formed at the posterior nodal point, which point closely coincides with

Fig. 26.



the posterior surface of the lens, and is about 15 mm. in front of the yellow spot.

In Fig. 26, let C D be an object for which the eye is accommodated. The lines C *c*, D *d*, drawn from the extremities of the object, cross at the nodal point N. The angle C N D, will be the visual angle under which the object C D is seen. The size of the angle depends upon the distance of the object as well as upon its magnitude, and the size of the image thus formed on

the retina will also depend upon the antero-posterior length of the eyeball.

Thus an object A B, which is as large as C D, but nearer to the eye, will be seen under a larger angle, the angle A N B being greater than C N D. It is also clear that the image formed on the retina will be smaller at 1, when the antero-posterior diameter of the eye is less, as in hypermetropia, than it is at 2, as in emmetropia, and that it will be larger in myopia, as at 3, where the eyeball is elongated. It is, therefore, easy to understand that a patient may be able to read the smallest type and still have some defect of refraction, unless the type be read at its proper distance (see Fig. 32).

It is by the unconscious comparison of things of known size, that we are able to estimate the distance of objects, and not by the visual angle alone.

Objects must therefore be of a certain size, and it has been found out, that to enable us to see a complex figure like a letter distinctly, each part of the figure must be separated from the others, by an interval, equal to not less than the arc subtending an angle of 1′ at the nodal point.

It has been shown (Fig. 24 B), that in the hypermetropic eye, when in a state of rest, parallel rays are brought to a focus behind the retina, so that instead of a clear, well-defined image, we get a circle of diffusion. Convex glasses render parallel rays passing through them convergent, so that by placing a lens of the right strength in front of the hypermetropic eye, we bring forward its focus on to the retina.

In myopia (Fig. 24, c), where the focus is in front of the retina, we succeed by concave glasses in carrying back the focus.

These lenses are spherical, and were until recently numbered according to their focal length in inches, a glass of 1 inch focus being taken as a standard. To this plan there were several objections. The standard glass being a strong one, weaker glasses had to be expressed in fractions. Thus a glass of 4 inch focus was one fourth the strength of the standard 1 inch, and was expressed as $\frac{1}{4}$. In addition to the trouble and inconvenience of working with fractions, the intervals between the lenses were most irregular, and, moreover, the inches of different countries vary. At the Ophthalmological Congress in 1872, it was decided to adopt a metrical scale of measurement. A lens of 1 metre focus was taken as the unit and was called a dioptre; a weak instead of a strong glass therefore being the unit, a lens of two dioptres is twice the strength of the former, and has a focal length of half a metre. Thus each lens is numbered according to its refracting power, and not, as in the old system, according to its focal length; so that we have a series composed of equidistant terms. The numbers 1 to 20 indicate the uniformly increasing power of the glasses.

The focal length of a lens is not expressed in the dioptric measurement; this can, however, always be found by dividing 100 cm. by the number of the lens; if it be 2 D. then the focal length will be 50 cm., if 10 D. then 10 cm.

The intervals between dioptres is somewhat large,

so that decimals ·25, ·50, ·75 of a dioptre were introduced; these work easily.

Convex glasses magnify and concave ones diminish the size of objects.

Accommodation.—In the normal eye, in a condition of complete repose, parallel rays come to a focus exactly on the rods and cones of the retina, and the object from which they come is therefore seen distinctly.

Rays from a near object proceed in a divergent direction, and come to a focus behind the retina; the object would not then be clearly seen, unless the eye possessed within itself the power of bringing rays of different directions into union on the retina.

This power of altering the focus of the eye at will, is called *accommodation,* and is due to an alteration in the form of the lens. That the eye possesses this power can easily be proved in many ways, apart from the conscious muscular effort; perhaps as simple a way as any to demonstrate it to oneself, is to look through a net held a short distance off, at some distant object. Either the net or the object can be seen distinctly, but not both at once. If the meshes of the net be looked at, then the distant object becomes indistinct, and on looking at the object the meshes become confused.

Accommodation, therefore, increases the refraction of the eye and adapts it to near objects. The changes which take place in the lens during accommodation are—

1st. The anterior surface becomes more convex and approaches the cornea.

2nd. The posterior surface becomes slightly more convex, but remains equally distant from the cornea.

That these changes take place may be proved in the following manner: a small candle flame, or other convenient object, being held on one side of the eye, so as to form an angle of 30° with its visual axis, an observer looking into the eye from a corresponding position on the other side, will see three images of the flame, the first upright, formed by the cornea, the second larger, upright and formed by the anterior surface of the lens, the third smaller and inverted, formed by the posterior surface of the lens; when accommodation is put in force, images one and three remain unchanged in shape and position; image two, which is that formed by the anterior surface of the lens, becomes smaller, more distinct, and approaches image one, proving that this surface of the lens has become more convex and has approached the cornea. In an emmetropic eye adapted for infinity, it has been proved that the radius of curvature of the anterior surface of the lens is 10 mm., when accommodated for an object 13·5 cm. off, it is changed to 6 mm.

The pupil also becomes smaller, the central part advances, while the peripheral part slightly recedes.

The alteration in the shape of the lens is due to the contraction of the ciliary muscle, which draws forward the choroid, thereby relaxing the suspensory ligament and allowing the elasticity of the lens to come into play. This elasticity is due to the peculiar watch-spring arrangement of the lens fibres.

When the ciliary muscle is relaxed the suspensory

ligament returns to its former state of tension, and so tightens the anterior part of the capsule, flattening the front surface of the lens.

FIG. 27.

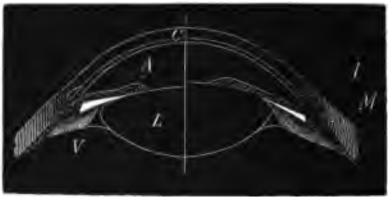


Diagram of lens, cornea, &c. The right half is represented as in a state of accommodation, the left half at rest. A. The anterior chamber. C. The cornea. L. The lens. V. The vitreous humour. I. The iris. M. Ciliary muscle.

When the muscle is thus relaxed to its uttermost, the lens has assumed its least convexity, and the eye is then adapted for its far point (*punctum remotum*) (*r*).

In this condition the eye is spoken of as being in a state of complete repose.

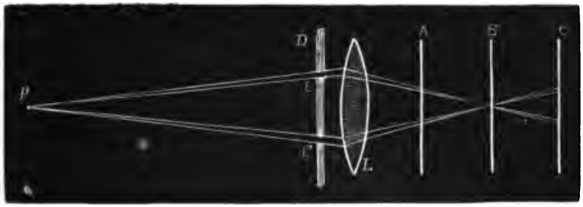
When the ciliary muscle has contracted as much as it can, the lens has assumed its greatest convexity, and its maximum amount of accommodation is now in force. This point is the nearest for which the eye can accommodate itself, and is called the *punctum proximum* (*p*).

In the emmetropic eye the punctum remotum is situated at infinity.

The position of the punctum proximum can be determined in several ways; the ordinary plan is to place in the patient's hand the small test type and note

the shortest distance at which he can read No. 1 with each eye separately; or we may measure it with the wire optometer, which consists of a steel frame crossed by thin vertical wires; this is supported in a handle to which a tape measure is attached, the tape is placed against the temple, and held there while the frame is made gradually to recede from the patient's eye we are examining, stopping as soon as the wires become distinct, and reading off the number of centimetres on the measure. Another excellent plan by which to find the position of the punctum proximum is that of Scheiner; close in front of the eye we wish to examine, is placed a card pierced with two small pin holes, which must not be further apart than the diameter of the pupil, through these two holes the patient is directed to look at a pin held about one metre away (the other eye is of course excluded from vision during the experiment); the pin will be clearly and distinctly seen, we then gradually approach it to the eye; at a certain place it will become double, the point at which the pin ceases to appear single will be the punctum proximum.

FIG. 28.



In Figure 28 the biconvex lens L represents the

eye, D the perforated card, P the pin, E E′, the two sets of rays from P, which focus exactly at B the retina. If, however, the pin be brought nearer, so that the accommodation is unable to focus the two sets of rays, they will form instead of one, two images of the pin on the retina as at A. These will be projected outwards as crossed images.

The distance between the punctum remotum and the punctum proximum is called *the range of accommodation.*

The force necessary to change the eye from its punctum remotum to its punctum proximum is styled the *amplitude of accommodation.* The amplitude of accommodation therefore is equal to the difference between the refracting power of the eye when in a state of complete repose, and when its maximum amount of accommodation is in force, and may be expressed by the formula $a=p-r$.

A convex glass placed in front of the eye produces the same effect as accommodation, *i.e.* it increases its refraction and adapts the eye for nearer objects. We can easily understand, that the lens which enables an eye to see at its near point without its accommodation, is a measure of the amplitude of accommodation, giving to rays which come from the near point a direction as if they came from the far point.

The amplitude of accommodation is the same in every kind of refraction. If we wish to measure it in an *emmetrope,* we have merely to find the nearest point at which the patient can read small print. A lens whose focal distance corresponds to this, is a measure of the

amplitude of accommodation. Thus, supposing 20 cm. the nearest distance at which he is able to read small print, we divide this into 100 cm. to find the focal distance of the lens ($\frac{100}{20}=5$ D.); and in this case a lens of 5 D. is the measure we require.

Or we can measure it in an inverse manner, by looking at a distant object through a concave glass; the strongest with which we can see this distant object distinctly, is the amplitude of accommodation; the concave glass giving to parallel rays coming from the distant object such an amount of divergence, as if they came from a point situated at the principal focal distance of this glass.

The Accommodation of Hypermetropes.—A hypermetrope requires some of his accommodation for distant objects; we must, therefore, in order to find the amplitude of accommodation in his case, add on to the lens whose focal length equals the distance of the near point, that lens which enables him to see distant objects, without his accommodation. Thus we will assume his near point to be 25 cm. ($\frac{100}{25} = 4$ D.), and that he had to use 4 D. of accommodation for distant objects, then the amplitude of his accommodation would be 4 D. + 4 D. = 8 D.

The Accommodation of Myopes.—In a myope we have to subtract the glass which enables him to see clearly distant objects, from that whose focal length equals the distance of the near point. Thus, to find the amplitude of accommodation in a myope of 2 D., the near point being at 10 cm., we subtract from ($\frac{100}{10}=10$) 10 D. the amount of the myopia 2 D. and the result-

ing 8 D. is therefore the amplitude of accommodation.

Hence it is obvious that with the same amplitude of accommodation, the near point is further away in hypermetropia than in emmetropia, and further in emmetropia than in myopia. Thus an emmetrope, with an amplitude of accommodation of 5 D. would have his near point at ($\frac{100}{5}=20$) 20 cm., a hypermetrope of 2 D., whose amplitude equalled 5 D. would require 2 D. for distance, leaving him 3 D., which would bring his near point to($\frac{100}{3}=33$) 33 cm.; and a myope of 2 D., who would require a concave glass of this strength to enable him to see at a distance, would have a near point of 14 cm.($\frac{100}{7}=14$) with the same amplitude.

FIG. 29.
Dioptres.

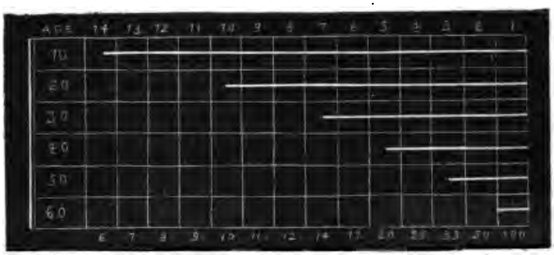


Diagram showing by the number of squares through which the thick lines pass, the amplitude of accommodation at different ages. The figures above, represent the number in dioptres of accommodation; those below, the near point for each amount; and those on the left, the age of the individual (*after Donders*).

Accommodation is spoken of as *absolute, binocular,* and *relative.*

Absolute, is the amount of accommodation which one eye can exert, when the other is excluded from vision.

Binocular, that which the two eyes can exert together, being allowed at the same time to converge.

Relative, that which the two eyes can exert together for any given convergence of the visual lines.

As age advances the elasticity of the lens diminishes, the ciliary muscle loses power, and the accommodation therefore becomes less, the near point gradually receding. These changes commence at a very early age, long before the individual has come to maturity.

Convergence.—This is the remaining element of distinct binocular vision, and with it accommodation is very intimately linked, so that usually for every increase of the convergence, a certain increase in the accommodation takes place.

Convergence is the power of directing the visual axes of the two eyes, to a point nearer than infinity; and is brought about by the action of the internal recti muscles.

When the eyes are completely at rest, the optic axes are either parallel, or more usually, slightly divergent. The angle thus formed between the visual and the optic axis, is called the angle *a*, and varies according to the refraction of the eye. In emmetropia the angle is usually about 5°; in hypermetropia it is greater, sometimes about 7° or 8°, giving to the eyes an appearance of divergence; in myopia the angle is less, often about 2°, or the optic axis may even, in extreme cases, fall

on the inside of the visual axis, when the angle *a* is spoken of as negative (p. 176) : so that in myopia there is frequently an appearance of convergence, giving one the idea of a convergent squint; hence the mere look of the patient's eyes, with regard to their axes is not always quite reliable.

The object of convergence, is the directing of the yellow spot in each eye towards the same object, so as to produce singleness of vision. Diplopia, or double vision, at once resulting, when the image of an object is formed on parts of the retina which do not exactly correspond in the two eyes.

To test the power of convergence, prisms are held with their bases outwards. The strongest prism which it is possible to overcome, that is, the prism which does not produce diplopia on looking through it at a distant object, is the measure of the convergence, and varies in different persons, usually between prisms of 20° and 30°, divided between the two eyes.

In considering convergence, we have not only to bear in mind the condition of the internal recti muscles, but also the state of equilibrium, produced by them and the action of their antagonists—the external recti.

The nearer an object, the more we have to use the power of convergence, and so also with the accommodation. Hence usually on converging to any particular point, we also involuntarily accommodate for that point, the internal recti and ciliary muscles acting in unison.

Nagel has proposed a very simple and convenient plan, by which we may express the convergence in metres, calling the angle formed by the visual and median lines as at M′, the *metrical angle.* The following is the plan, in Fig. 30 : E, E′ represent the centres of rotation for the two eyes; E H E′ is the base line between the eyes. When the eyes are fixed on some distant object, the convergence being passive, the visual lines are parallel or almost so, as E A, E′ A′, the angle of convergence is then at its minimum, and it is said to be adapted to its *punctum remotum,* this, then, being at infinity is expressed, $C = \infty$.*

If the eyes be directed to an object one metre away, the metrical angle E M′ H equals one, *i.e.* $C=1$. If the object is 50 cm. off, then $C=2$; if 10 cm. then $(\frac{100}{10}=10)$ $C=10$. If the object had been beyond 1 metre (our unit), but not an infinity, say 4 metres, then $C = \frac{1}{4}$.

When the visual lines, instead of being parallel, diverge, then the punctum remotum is found by continuing these lines backwards till they meet at C, behind the eye, the convergence is then spoken of as *negative.*

When the eyes are directed to the nearest point at which they can see distinctly, say at M‴, the angle of convergence is at its maximum, and it is said to be adapted to its *punctum proximum.*

The difference between the punctum proximum and the punctum remotum is the *amplitude of convergence.*

We know also that the accommodation increases the

* C is the sign for convergence, and ∞ the sign for expressing infinity.

Fig. 30.

nearer the object approaches, hence we see, that both the convergence and accommodation increase and decrease together; and in recording the convergence in the manner proposed by Nagel, it will be seen on referring to the foregoing figure, that in the emmetropic eye the number which expresses the metrical angle of convergence, expresses also the state of refraction for the same point—this is a great advantage. Thus when looking at a distant object, the angle of convergence is at infinity, $C=\infty$, and the refraction is also at infinity, $A=\infty$. When the object is at 1 metre the angle of convergence $=1$, and the amount of accommodation put into play $=1$ D. When the object is at 25 cm. then the angle of convergence $=4$, and the amount of accommodation $=4$ D.

It has been found by experiment, that the amplitude of convergence is somewhat greater than the amplitude of accommodation, passing it both at its punctum remotum and its punctum proximum.

The following table from Wecker and Landolt, shows the angle of convergence in degrees, for different distances of the object, when the eyes are 6·4 cm. apart:

Distance of the object from the eyes.		The metrical angle.		Value expressed in degrees.
1 metre	...	1	...	1° 50′
50 cm.	...	2	...	3° 40′
33 ,,	...	3	...	5° 30′
25 ,,	...	4	...	7° 20′
20 ,,	...	5	...	9° 10′
16 ,,	...	6	...	11°
14 ,,	...	7	...	12° 50′

Distance of the object from the eyes.		The metrical angle.		Value expressed in degrees.
12 cm.	...	8	...	14° 40′
11 „	...	9	...	16° 30′
10 „	...	10	...	18° 20′
9 „	...	11	...	20° 10′
8 „	...	12	...	22°
7·5 „	...	13	...	23° 50′
7 „	...	14	...	25° 40′
6·5 „	...	15	...	27° 30′
6 „	...	16	...	29° 20′
5·5 „	...	18	...	33°
5 „	...	20	...	36° 40′

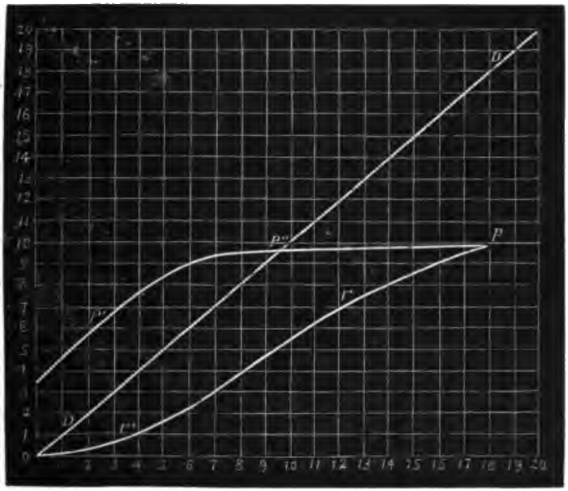
Although accommodation and convergence are thus intimately linked together, it can easily be proved that they may have a separate and independent action. If we suspend the accommodation with atropine, the convergence is not interfered with, and if by division of both the internal recti for squint, the power of convergence is for the time lost, the accommodation can still be brought into play. Again, an object at a certain distance being seen clearly without a glass, can still be seen distinctly with weak concave and convex glasses.

The following diagram (Fig. 31) shows the relative amount of accommodation for different points of convergence in an emmetrope, aged fifteen. The amount of accommodation in excess of the metrical angle of convergence is called *positive,* and the amount below *negative.*

The diagonal D D represents the convergence from infinity to 5 cm.; it is also a record of the accommodation. The line P P′ P″ indicates the maximum accommodation for each point of convergence, and the

line *r r′* the minimum. The numbers on the left and below the diagram are dioptres and metrical angles of convergence; thus, when the visual lines are parallel, it will be seen that 3·5 D. of positive accommodation can be put into play, *i.e.* the object can still be seen distinctly with a concave glass of that strength, 3·5 D. is therefore the relative amplitude of accommodation for convergence adapted to infinity; or the metrical angle C being 5, which is a distance

FIG. 31 (*Donders*)



of 20 cm. away, the accommodation for that point would equal 5 D.; the positive amount that can be put in force while angle C remains the same, would be 3 D., and the negative also 3 D., the object being seen clearly

with a concave or convex glass of 3 D., therefore, the relative amplitude of accommodation for C 5 is 6 D. When the angle C=10 or any larger angle, the accommodation that can be put in force will be seen to be entirely on the negative side.

Thus, the convergence being fixed, the amount of accommodation which can be brought into play for that particular point, is the sum of the difference between the strongest concave and convex glass employed.

The eye being accommodated for an object at a certain distance, the amount of convergence for that particular point, may be measured by placing in front of the eyes, prisms bases outwards, the strongest with which the object is still seen singly, is the measure of the positive part of the amplitude of convergence. Prisms, bases inwards, give us the negative part—the sum of these is the amplitude of relative convergence.

CHAPTER III

METHODS OF DETERMINING ERRORS OF REFRACTION

I NOW propose to enter into the practical part of the subject by considering the following objective and subjective methods by which errors of refraction may be diagnosed and estimated :

1. The acuteness of vision.
2. The indirect and direct ophthalmoscopic examinations.
3. Scheiner's method.
4. Retinoscopy.

In every case that presents itself we must proceed in a systematic manner, and before commencing to take the patient's visual acuteness, something may be gained by noticing the general appearance of the patient, the form of the face, head, &c. ; thus, a flat-looking face is sometimes an indication of hypermetropia ; a head elongated in its antero-posterior diameter, with a long face and prominent nose, may indicate myopia. If the two sides of the face are not symmetrical, or if there be some lateral displacement of the nose from the median line, astigmatism may be suspected. We should also notice the shape of the eyes themselves, if large and prominent or small, in the

former case we may suspect myopia, in the latter hypermetropia. In high degrees of astigmatism it can often be seen that the curvature of one meridian exceeds that of the other. The distance between the eyes should also be noted, as well as the direction of their axes.

We next listen to the patient's own statement of the troubles from which he suffers; he may say that he sees distant objects well but has difficulty in reading, especially in the evenings, or that after reading for some time the type becomes indistinct so that he must rest awhile, here we suspect hypermetropia; or he may be able to read and do near work but sees badly at a distance, then we suspect myopia; or both near and distant vision may be defective, in this case our first object must be to decide whether the imperfect vision is due to some error of refraction or to some structural change in the eyes themselves; and we possess an exceedingly simple method by which to differentiate between them, and this method we will call the **Pin-hole** test. A black diaphragm having a small perforation in its centre (the box of trial glasses usually contains such a diaphragm) is placed quite close to the eye under examination, the perforation gives passage to a small pencil of rays which passes through the axis of the refracting system of the eye so that the image formed is clearly defined for all distances; if then the pin-hole improve vision, the refractive system is at fault, but if, on the contrary, vision is not improved, then we suspect that the transparency of the media or that the retinal sensibility is defective; thus we possess a

very simple and reliable plan, which if used systematically may save much loss of time. The points to notice when applying this test are, that the illumination is good, and that the pin-hole is immediately in front of the centre of the pupil. Having, then, found out that our patient's refraction is defective, we proceed to our first method, the acuteness of vision.

The Acuteness of Vision.—This must not be confused with the refraction, you must understand clearly the difference between them; the acuteness of vision is the function of the nervous apparatus of the eye, while the refraction is the function of the dioptric system, so that the acuteness of vision may be normal, even if the refraction be very defective, provided it has been corrected by glasses. The refraction, on the other hand, may be normal even though the eye is unable to see, as in cases of optic atrophy, &c.

So that we may define the *acuteness of vision* as that degree of sight which an eye possesses after any error of its refraction has been corrected, and the glasses necessary for this correction are therefore a measure of the error of refraction.

In order to find out the acuteness of vision, we have to determine the smallest retinal image, the form of which can be distinguished; it has been discovered by experiments that the smallest distance between two points on the retina which can be separately perceived is 0·00436 mm., about twice the diameter of a single cone; but it is only at the macula and the part immediately around it, which is the most sensitive part of the retina, that the cones are so close together as ·002

mm.; in the periphery of the field of vision the two points must be further apart to appear distinct.

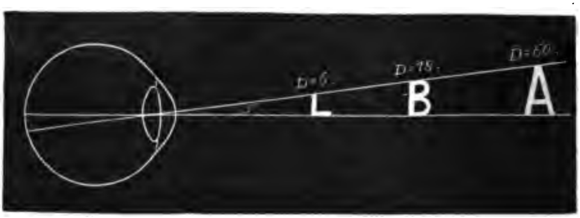
It is probable that rays from two points must fall upon two different cones in order to be visible as two distinct points.

The smallest retinal image which can be perceived at the macula corresponds to a visual angle of 1′, so that two stars separated by an angular interval of less than 1′ would produce upon the eye the effect of one star only.

The visual angle has been shown to be an angle included between two lines drawn from the two opposite edges of the object through the nodal point (Fig. 26).

Test types have been constructed upon these principles for determining the acuteness of vision; Snellen's being those ordinarily used. Every letter is so made that when at its proper distance each part of it is separated from the other by an interval equal to not less than the arc subtending an angle of 1′ at the nodal point, and the whole letter subtending an angle of 5′.

Fig. 32.



In order to estimate the refraction by the acuteness of vision, the test object must be placed in a good

light, and so far away as to exclude as much as possible the accommodation, 6 metres has been found to be a sufficient distance, and rays coming from an object so far off, may be assumed to be parallel, and falling on an emmetropic eye at rest, would come to a focus on the retina. The smallest letter which can be seen distinctly at this distance will represent the patient's vision.

Snellen's type consists of rows of letters, each being marked above with the distance in metres at which it should be read. The top letter should be distinct at 60 metres, the next at 36, and each succeeding row at 24, 18, 12, 9, and 6 metres respectively.* The patient placed at 6 metres should, without any accommodation, be able to read the bottom line with either eye. This is expressed in the form of a fraction in which the numerator is the distance at which it is read, and the denominator, the number of the line. We note down the result found for each eye separately, if the bottom line is read, $\frac{6}{6}$ expresses it, if the next $\frac{6}{9}$, the top $\frac{6}{60}$, &c.

If our patient, however, be not able even to see the large letter at the top, we allow him to approach the board, telling him to stop as soon as the letter becomes visible. Supposing he stop at 2 metres from the board, we express that as $\frac{2}{60}$, if he is not able to

* The set of test type at the end of the book has an additional line to those generally used and is marked 5, so that a greater amount of visual acuteness than the normal $\frac{6}{6}$ can be estimated, and is, of course, recorded $\frac{6}{5}$. This set of type is also convenient for those who prefer working at five metres.

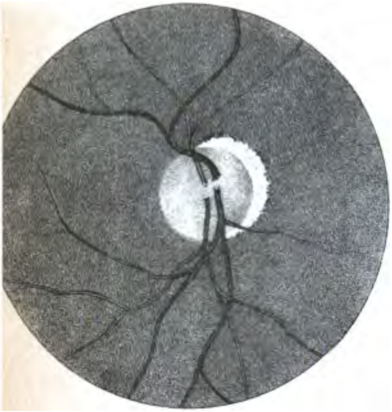
read it at all, we see how far off he can count fingers. If unable to do this, a lower degree of visual acuteness is found out by determining the ability to distinguish different sorts of light, as to colour, &c. This is called "qualitative perception of light," whereas a still lower degree is to distinguish the difference between light and darkness, this is "quantitative perception of light."

Although the capability of reading the bottom line at six metres is the average of acuteness at different ages, yet it is not the maximum, since many young people will be found who are able to read line six at 7 metres, in which case their acuteness is $\frac{7}{6}$.

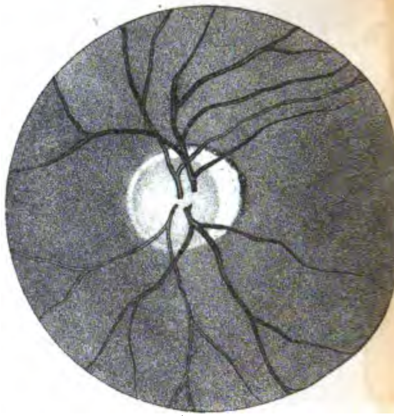
Savages also often have an acuteness of vision much in excess of the normal.

Thus we have a standard of normal vision, and a convenient method of expressing it in a numerical manner.

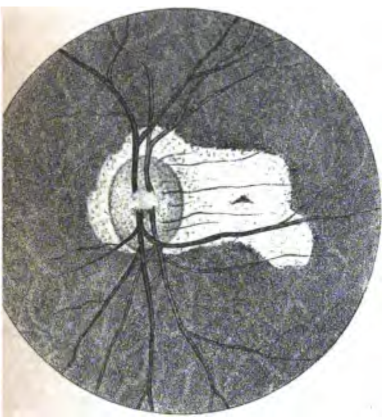
We put our patient then, with his back to the light, in front of the test-types, which must hang well illuminated at 6 metres distance, and having armed him with a pair of trial frames, we exclude the left eye from vision, by placing in front of it a ground glass disc, and proceed to test the right eye by asking him, how much of the type he is able to read, if he read the line marked 6, then his vision is $\frac{6}{6}$ or 1, that is to say, his distant vision is normal; we may, therefore, assume the absence of *myopia* or *astigmatism*, but he may have *hypermetropia*, and only be able to to read $\frac{6}{6}$, by using his accommodation, this we decide, by holding a weak convex glass (+ ·5 D.) in front of



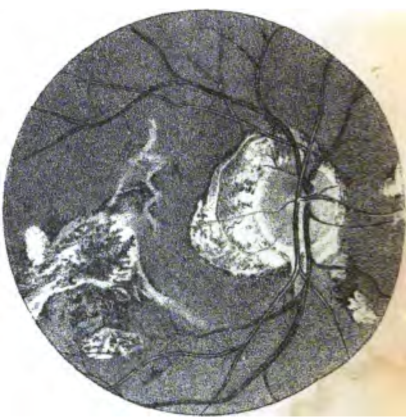
1.



2.



3.



4.

Danielsson & C°

the eye, when, if he still be able to read the same line $\frac{6}{6}$, he has hypermetropia, and the strongest convex glass with which $\frac{6}{6}$ can be read, is the measure of the *manifest* hypermetropia; supposing + 1 D. the strongest glass with which $\frac{6}{6}$ can be read, then we record it thus: R. V. $\frac{6}{6}$ Hm. 1 D. = $\frac{6}{6}$.

I say manifest hypermetropia, because in all cases occurring in young people, this is not the total hypermetropia; a great part being latent, which can only be discovered by using atropine. Many cases will come before us having two or three dioptres of hypermetropia, who complain that the weakest convex glass impairs distant vision, in these cases the hypermetropia is wholly latent.

We may say, therefore, that a patient who is able to read $\frac{6}{6}$ must be—

Emmetropic
or
Hypermetropic.

If hypermetropic, a part of it is usually *manifest*, as found out by the *strongest* convex glass which does not impair distant vision, or it may be wholly *latent*, when it is necessary to atropise the patient before we can demonstrate it.

Supposing, however, our patient's vision is below the normal, and instead of reading $\frac{6}{6}$ is only able to read, say the third line ($\frac{6}{24}$), and that this is blurred with a weak convex glass, he may have:

Myopia,
Astigmatism,
or
Spasm of accommodation (see Chapter IX).

We try if a weak concave glass helps him, and if it does so, the case is one of myopia and we find the *weakest* concave glass with which he sees best; thus we take an example in which the patient is a myope and sees only $\frac{6}{24}$, but with $-$ 2 D. $\frac{6}{6}$, we repeat the examination with the second eye, and record it accordingly.

R. V. $\frac{6}{24} - 2$ D. $= \frac{6}{6}$.
L. V. $\frac{6}{24} - 2$ D. $= \frac{6}{6}$.

If our patient is not improved with concave glasses, then we assume that some astigmatism is present, presupposing of course that there is no other cause for bad vision.

We find out the spherical glass with which he is able to see best, then rotate in front of it a weak convex cylindrical glass; no improvement occurring we do the same with a weak concave cylinder, finding thereby, the glass and its particular axis, which gives the best result. It is absolutely necessary that the eye be thoroughly under the influence of atropine, in order to enable us to arrive at definite results by this method. With practice one is able in this way, to work out simple cases of astigmatism accurately and quickly.

The object in view is always to bring up the vision of each eye, as nearly to the normal standard of $\frac{6}{6}$ as possible. Frequently, however, we have to be satisfied with $\frac{6}{9}$ or $\frac{6}{12}$.

When trying the patient at the distant type, it is often convenient to have two sets on the opposite sides of the same board, so that it may be reversed when the patient gets too accustomed to the letters on one side.

The near type is chiefly used to estimate the accom-

modation, by finding out the far and near point, at which any particular line is read. Snellen and Jaeger's are the types most commonly in use, many preferring Jaeger's, owing to the letters being of the ordinary shapes, but they have the disadvantage, that they are not arranged on any scientific plan, but are simply printer's type of various sizes: the set of reading type at the end of the book is so arranged that when held at the distance for which it is marked each letter subtends an angle of 5′ at the nodal point. It must, however, be remembered that sentences are an inferior test to letters, many people recognising the words by their general appearance, whereas they would be unable to see distinctly each letter, of which the sentence was composed.

Having tested our patient's vision at the distant type and recorded the result, we place in his hand the near type, and note the near and far point at which any particular line can be read.

In cases of myopia we may thus get a valuable hint, as to the amount of the defect; we will take for an example a case, in which the patient could read $\frac{6}{24}$ with the right eye, we give him the near type and if he can read the smallest, though at a *nearer* point, than the distance for which it is marked, we note the *greatest* distance at which he is able to read it; we will take a case in which the type marked for 1 metre, cannot be read further off than 25 cm., our patient has then most likely myopia of 4 D., because 25 cm. is probably his far point. In this case a glass – 4 D. would give to rays coming from a distant point,

the same amount of divergence, as if they came from 25 cm. ($\frac{100}{25} = 4.$)

We try the patient at the distant type with -4 D.; if he now read $\frac{6}{6}$ the myopia is confirmed, and the weakest glass with which he reads it, is the measure of his myopia.

If the patient read $\frac{6}{6}$, but be unable to read the near type, except it be held at a further distance than that for which it is marked, he has presbyopia, if however, he be much younger than forty-five, the age at which presbyopia usually commences in emmetropia, it is probably a case of paralysis of the accommodation.

As convex glasses magnify, and concave glasses diminish the size of objects, it follows that these, when placed before the eye, will exercise some influence on the size of the retinal image. Now the hypermetropic eye sees objects smaller, and the myopic eye larger than the emmetrope, and Landolt says, that if glasses which are to correct the ametropia be placed "13 mm. in front of the cornea, the retinal image of the ametrope, should be of the same size as that of the emmetrope."

Before leaving this subject of the acuteness of vision, the following directions may be given:

1st. The test type must be in a good light.

2nd. Commence with the right eye, or that which has the best vision, covering up the other with an opaque disc placed in a spectacle frame, and do not be contented to allow the patient to close one eye, as he may not do so completely, or he will probably uncon-

sciously slightly diminish the palpebral aperture of the eye under examination, whereby the circles of diffusion may be somewhat diminished and so give misleading results. Neither should he close the eye with his hand, he may look between the fingers, or exercise some pressure, however slight, on the eyeball, which may interfere temporarily with the function of the retina and so cause delay.

3rd. Having noticed what each eye sees without glasses, always begin the examination with *convex* ones, so as to avoid calling the accommodation into action.

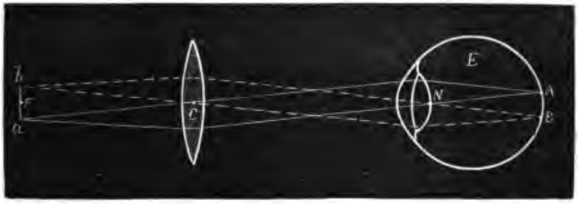
4th. Having noted the result found for each eye separately, we try the two together, the binocular visual acuteness being usually slightly greater than that for one eye.

5th. Try the patient with the reading type.

The Ophthalmoscope furnishes us with several methods for determining the refraction of the eyes.

By the **indirect method**, we obtain an inverted image of the disc by means of a biconvex lens placed in front of the eye. In emmetropia (Fig. 33) rays

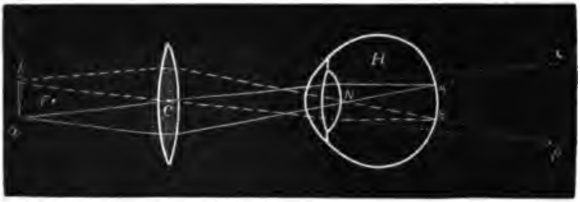
FIG. 33.



coming from A, emerge from the eye parallel, and are focussed by the biconvex lens at *a*, and rays coming

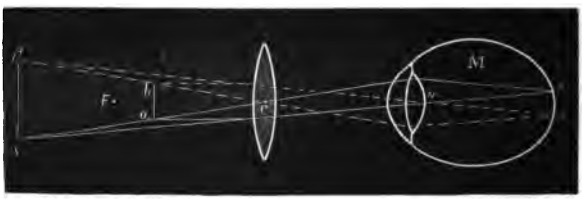
from B are focussed at *b*, so also with rays coming from every part of A B, forming an inverted image of A B at *b a*, situated in the air at the principal focus of the bi-convex lens.

FIG. 34.



In hypermetropia (Fig. 34) the rays from A emerge divergent, so also of course those from B; if these rays are continued backwards, they will meet behind the eye (at the punctum remotum) and there form an enlarged, inverted image (α β) of A B; it is of this imaginary projected image, that we obtain by the help of the bi-convex lens a final inverted image (*b a*), situated in front of the lens beyond its principal focus.

FIG. 35.



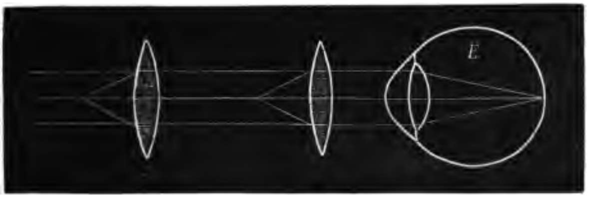
In myopia (Fig. 35) the rays from A and B emerge from the eye convergent, forming an inverted aërial image in front of the eye at β α, its punctum remotum.

It is of this image we obtain with a biconvex lens placed between it and the eye, a final image (*b a*), situated within the focus of the biconvex lens.

With this method we are able to detect the form of ametropia, by the changes which take place in the size and shape of the optic disc, always remembering that the inverted image of the disc, produced by a convex lens at a certain fixed distance from the cornea, is larger in hypermetropia, and smaller in myopia, than in emmetropia. The lens should be held close to the patient's eye, and as it is gradually withdrawn, the aërial image of the disc being steadily kept in view the while, the rapidity with which any increase or decrease takes place in the size of this image, gives us an indication of the amount of the refractive error.

If no change take place in the size of the image on thus withdrawing the objective, the case is one of emmetropia, because rays issue from such an eye,

FIG. 36.



E. Emmetropic eye. Rays issuing parallel, image formed at the principal focus of lens, no matter at what distance the lens is from the eye.

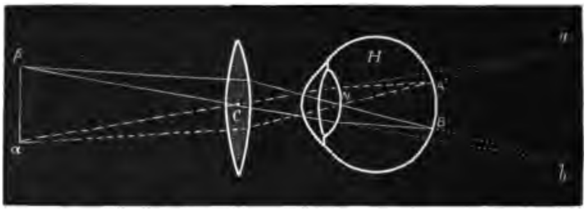
parallel, and the image formed by the object-glass will always be situated at its principal focus, no matter at what distance the glass is from the observed eye (Fig.

36). As the relative distance of the image and the object from the lens is the same, the size of the image will also be the same.

If diminution take place in the size of the image, the case is one of hypermetropia, and the greater the diminution the higher is the hypermetropia.

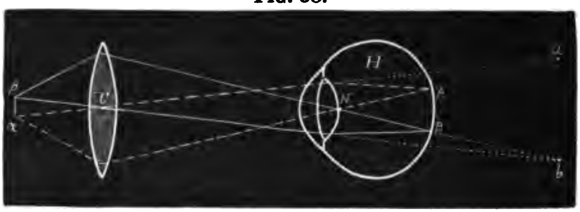
This change in size may be explained by remembering that in hypermetropia, the image of the disc is

Fig. 37.



Lens at 4 cm.

Fig. 38.



Lens at 12 cm.

H. Hypermetropic eye. C. The centre of the lens. A B. Image on retina. *a b*. Projected image. *β a*. The final image formed by the objective.

projected backwards (Fig. 40), and it is of this projected image, we obtain a final image with the help of

the objective. The two diagrams show images formed by the object-glass, when held at 4 cm. and at 12 cm. from the cornea, the latter image being the smaller.

The following explains this :

The ratio of *a* β to *a b* varies directly as the length C *a*, and inversely as the length C *a*; on withdrawing the lens C from the observed eye, C *a* diminishes and C *a* increases; therefore the ratio of *a* β to *a b* diminishes, *i.e.* the size of the image diminishes.

If the image becomes larger on withdrawing the object-glass, the case is one of myopia, the greater the increase of the image, the higher the myopia.

This increase in the size of the image can also be explained with the help of mathematics, remembering that in myopia an inverted image is formed in front of the eye (Fig. 41), and it is of this we obtain an image, with a convex glass placed between the eye and the inverted image, which we must regard as the object; the object and its image being both on the same side of the lens.

In astigmatism the disc, instead of appearing round, is frequently oval. If one meridian decrease, while the other remain stationary as the objective is withdrawn, it is a case of simple hypermetropic astigmatism. If the whole disc decrease in size, one meridian diminishing more than the other, it is compound hypermetropic astigmatism, the meridian being most hypermetropic which diminishes most.

Increase in one meridian, the other remaining stationary, indicates simple myopic astigmatism.

Increase in disc, but one meridian more so than the

other, indicates compound myopic astigmatism, that meridian being most myopic which increases most.

If one meridian increase while the other decrease, mixed astigmatism is our diagnosis.

By the **direct examination** we obtain much more important information, not only of a qualitative but also of a quantitative character.

The observer first of all corrects any ametropia that may exist in his own eye. If he be able to see the disc or some of the vessels, with the mirror alone at a distance from the patient, the case is one of hypermetropia or myopia. The explanation of this is, that in emmetropia (Fig. 39) the rays which come from the

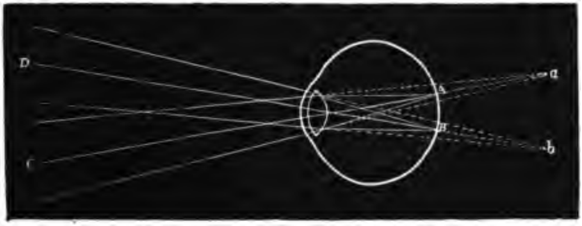
FIG. 39.

two extremities of the disc (A B), emerge as two sets of parallel rays in the same direction as the rays A C, B D, which, having passed through the nodal point, undergo no refraction. These two sets of rays soon diverge, leaving a space between them, so that an observer, unless he be quite close to the observed eye, is unable to bring these rays to a focus on his retina; and therefore, at a distance from the eye the observer sees only a diffused and blurred image.

In hypermetropia (Fig. 40), the rays from the two

points A B, emerge from the eye in two sets of diverging rays, in the same direction as the rays A C, B D, which undergo no refraction. These diverging rays have the appearance of coming from two points (*a*, *b*) behind the eye, where an erect imaginary image is formed (*a b*).

FIG. 40.

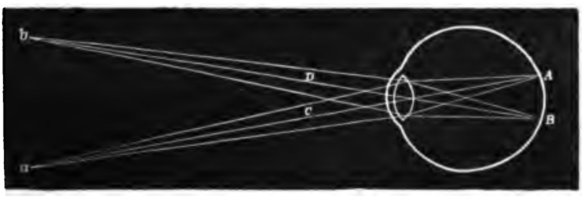


The more the rays diverge on exit, the sooner they will meet when prolonged backwards; and hence, the greater the hypermetropia, the nearer will the image be to the nodal point.

The observer at a distance sees a clear, erect image, which is formed behind the eye.

In myopia (Fig. 41), the rays from the two points (A

FIG. 41.



B) emerge as two converging sets of rays, which meet at *a b* on their secondary axes, thus forming an inverted

image in front of the eye. This image can be distinctly seen by the observer, if he be at a sufficient distance from the point, and accommodating for the particular spot at which the aërial image is formed, and the higher the myopia the nearer to the eye will this image be formed.

If the observer now move his head from side to side, and the vessels of the disc are seen to move in the same direction, the case would be one of hypermetropia, the image formed being an erect one.

Had the vessels moved in the opposite direction to the observer's head, the case would be one of myopia, the image being an inverted one formed in the air in front of the eye.

If the vessels of one meridian only are visible, then we have a case of astigmatism, hypermetropic if moving in the same, and myopic if moving in the opposite direction to the observer's head, that meridian being ametropic which is at right angles to the vessels seen.

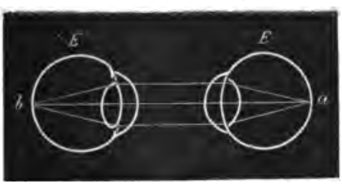
In mixed astigmatism the vessels of one meridian move against the observer's movements, and those of the other meridian with them; this is difficult to see.

Thus we have obtained an indication of the form of ametropia. We may, however, estimate the amount of error, by means of a refracting ophthalmoscope, of which there are many.

In endeavouring thus to estimate the refraction, it is essential that the accommodation of both the patient and observer be suspended. The observer places both himself and the lamp on the same

side as the eye he is about to examine, then, with the mirror close to the patient's eye, so that the ophthalmoscope may occupy as nearly as possible the position of the spectacle glass, he looks for the disc. We really wish to estimate the refraction at the macula, but to this there are several obstacles: the light falling on this, the most sensitive part of the retina, has a very dazzling, unpleasant effect for the patient, and causes the pupil to contract vigorously, the reflex from the cornea and the lens is exactly in the line of vision, and further, there are no convenient vessels in this part, which we may fix as test objects, whereas, the disc is but little sensible to light, and the vessels of this part, as well as the margins of the disc itself, are very convenient for our purpose; and although occasionally the refraction of the macula and disc are not exactly the same, still, practically it is sufficiently accurate to take that of the latter. Having relaxed the patient's accommodation by making the examination in a dark room, and directing him to look with the eye not under examination into space, or, what is

FIG. 42 (*Landolt*).

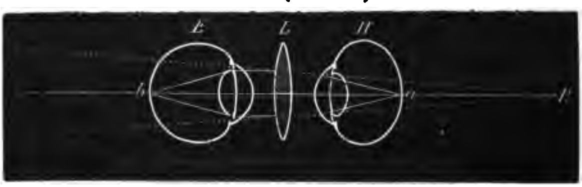


better, having paralysed it by atropine, then, if the observer's own accommodation be suspended, and the image of the disc appear quite clear and distinct,

the case is one of emmetropia. This we know, because rays coming from an emmetropic eye (fig. 42, E) in a state of repose, issue parallel according to the law of conjugate foci, and the observing eye receiving these rays will, if emmetropic with its accommodation suspended (which often requires great practice), be adapted for parallel rays, so that a clear image of *a* in the observed eye, will be formed at *b* on the retina of the observing eye.

Supposing the image does not appear clear and distinct without an effort of accommodation, then we turn the wheel of the ophthalmoscope so as to bring forward convex glasses in front of the observing eye. The *strongest* positive glass with which we are able to get a perfectly clear image, is a measure of the hypermetropia, because rays coming from *a* (Fig. 43) in the

FIG. 43 (*Landolt*).



hypermetropic eye (H) issue in a divergent direction as though coming from R, the punctum remotum behind the eye. The convex lens (L) renders them parallel and they then focus at *b*, on the retina of the observing emmetropic eye (E).

In practice many observers find it difficult or impossible to tell if their own accommodation be com-

pletely relaxed, so that if they see clearly the disc of the patient under examination, they do not at once assume that he is emmetropic, but only do so, on finding that the weakest convex glass behind the ophthalmoscope impairs the clearness of the image.

If the convex glass, instead of rendering the image more distinct, have the opposite effect, we must turn the wheel of the ophthalmoscope in the other direction, thus bringing forward the concave glasses. The *weakest* with which we can see the details of the fundus, is a measure of the myopia, because any stronger glass merely brings into play the accommodation of the observer. Rays from *a* (Fig. 44) leave the myopic

FIG. 44 (*Landolt*).

eye (M) so convergent, that they would meet at (R) the punctum remotum. The concave lens (L) renders them parallel before falling on the relaxed eye (E) of the observer.

If the ophthalmoscope is not held very close to the eye, we must deduct from the focal distance of the lens, the distance between the cornea and the instrument in hypermetropia, adding them together in myopia.

If astigmatism exist, the plan is to find the glass

which enables the vertical vessels and lateral sides of the disc to be seen distinctly, and then the glass with which the vessels at right angles are best seen.

Suppose the vertical vessels and lateral sides of the disc appear distinct without any glass, then the horizontal meridian, *i.e.* the meridian at right angles to the vessels clearly seen, is emmetropic; and suppose, also, that the horizontal vessels with the upper and lower borders of the disc, require a convex or concave glass to render them clear and distinct, then, the vertical meridian is hypermetropic or myopic, and the case is one of simple hypermetropic or myopic astigmatism.

If both the vertical and horizontal vessels require convex glasses, but a stronger one for the horizontal than for the vertical, then the case is one of compound hypermetropic astigmatism, the vertical meridian being most hypermetropic.

If both meridians had required concave glasses, but of different strengths, then the case would be one of compound myopic astigmatism.

If the vertical vessels and the lateral sides of the disc require a convex glass to render them distinct, while the horizontal vessels require a concave glass, the case is one of mixed astigmatism, the horizontal meridian being hypermetropic, the vertical meridian myopic.

The essential point to remember is, that the glass with which the vessels in one direction are seen, is a measure of the refraction of the meridian at right angles to them.

The estimation of the refraction by the direct ophthalmoscopic examination is exceedingly valuable but requires great practice. In cases of hypermetropia and low myopia, one is able to estimate the amount of error within half a dioptre, and in cases of astigmatism where the chief meridians are horizontal and vertical, one can come very near the exact correction, and without subjecting the patient to the inconvenience of having his accommodation paralysed with atropine, which in many cases is of great advantage; some observers are able to find out the exact meridians, even when oblique, and estimate correctly the most difficult cases of regular astigmatism; in such I must say that I have found this method of examination give less satisfactory results than retinoscopy, and I never venture to order glasses for astigmatism on the result of my direct ophthalmoscopic examination without confirming the result by some other method, but I am aware that some ophthalmic surgeons do so. No doubt the direct ophthalmoscopic examination requires much greater practice than any other method of examination; probably many observers can never relax their accommodation so completely as to give satisfactory results. It is also an additional advantage that one can estimate the refraction at the same time that one makes an examination of the fundus.

The comparison of the direct and indirect methods of examination is also very useful in astigmatism. If, for instance, the disc is elongated horizontally in the erect, and oval vertically in the inverted image, we know that the curvature of the cornea is greater in

the horizontal than in the vertical meridian (see Figs. 78 and 79).

The ametropic observer must always remember, when using the direct ophthalmoscopic method, for the estimation of errors of refraction, that he must correct his own defect, either by wearing spectacles or by having a suitable glass in a clip behind his ophthalmoscope; he is then in the position of an emmetrope, but, if he prefer it, he may subtract the amount of his own hypermetropia or myopia from the glass with which he sees clearly the patient's disc. Thus, if the observer have 2 D. of hypermetropia and require + 3 D. to see the fundus clearly (3 D. − 2 D. = 1 D.), the patient would have 1 D. of hypermetropia; had he required − 2 D. then (− 2 D. + (− 2 D.) = − 4 D.) the observed would have myopia of 4 D.

The same with the myopic observer, if his myopia amount to 3 D., then he will require − 3 D. to see clearly the emmetropic fundus; if he see well without a glass, then the eye under examination has 3 D. of hypermetropia; if he require a + 2 D., then the hypermetropia will be 5 D., and so on.

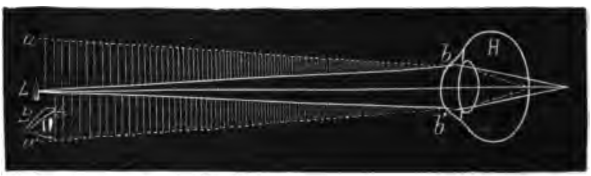
Scheiner's method.—Although this plan for detecting ametropia is now but little used, it is necessary the student should understand the principles upon which it is based. A diaphragm having two small perforations is placed in front of the eye we wish to examine; the perforations must be so near together that rays passing through them will enter the pupil (Fig. 28). The patient is directed to look at a small flame 6 metres off; rays emanate from this flame in all

directions, some fall on the diaphragm, the greater number are thus cut off, but a few rays pass through the two openings, and if the eye be adapted for the flame, *i.e.* if it is emmetropic, these two sets of rays will meet exactly on the retina, forming there one image of the flame (B, Fig. 28); if, however, the eye be hypermetropic (with suspended accommodation) then the two sets of rays will reach the retina before meeting, each set forming an image of the flame (A, Fig. 28). The greater the hypermetropia the further apart will the images be formed; these are projected outwards as crossed images, and the patient sees two images of the flame. That convex glass (from our trial box) which, held behind the diaphragm, causes the flame to be seen singly is a measure of the hypermetropia. If the eye be myopic, then the two sets of rays will have crossed and are diverging when they reach the retina, where two images of the flame are therefore formed (C, Fig. 28). These images are crossed again as they are projected outwards, and having twice crossed, the result is homonymous images. To find the amount of myopia we have only to find the concave glass which, behind the diaphragm, brings the two images into one. To enable us to tell if the images are crossed or homonymous, it is usual to have in front of one of the perforations a piece of coloured glass. We will suppose the diaphragm held so that the two openings are horizontal, that to the patient's right having in front of it a piece of red glass; if only one flame is seen the case is one of emmetropia, if two images of it appear, one white the other red, with the

red to the left of the other, the images are crossed and the case is one of hypermetropia. If the red appeared on the right then the case is one of myopia. The further apart the images are, the greater is the ametropia.

Ametropia may also be easily recognised in the following manner, as was pointed out to me by Mr. W. Odillo Maher, late house surgeon at Moorfields. The fundus being illuminated by a mirror about 1 metre from the patient, if the eye be emmetropic the rays of light will return parallel to one another, and a red reflex can only be obtained when the observing eye is in the path of these rays, that is, behind the perforation of the mirror. If hypermetropic the returning rays will diverge (Fig. 45), and

Fig. 45.



the observer will notice as he moves his eye (B) from behind the mirror at L, and at right angles to the visual axis of the patient who should fix on the centre of this mirror, that the last ray of light (a' b') is seen, or, in other words, the red reflex disappears, on the same side of the pupil as that to which the observer moves his head. If myopic, the rays will converge, cross, and diverge (Fig. 46); when the error is 1 D.

FIG. 46.

or more the last ray of light is seen, or the red reflex disappears on the opposite of the pupil. A single trial of this will prove its correctness.

Mr. Maher endeavoured to estimate the amount of myopia or hypermetropia by measuring the distance between the perforation of the mirror, and the point at which the last ray was seen; at present the varying size of the pupil is the obstacle.

The ophthalmometer of Javal and Schiötz and Tweedy's optometer, can I think, be more conveniently considered when treating of astigmatism.

CHAPTER IV

RETINOSCOPY

Retinoscopy is at the present time one of the most popular objective methods of estimating the refraction of the eye in this country, though in some others its adoption has been very slow.

Not only is it suitable in all cases of errors of refraction, but it can be easily applied in children, in those that are amblyopic and in malingerers.

The method of employing retinoscopy is so simple, that a few practical trials will suffice to make it understood, although, of course, as in all other manipulations, some little practice is required in giving to the mirror the necessary movements, and enabling one to appreciate what is seen.

Atropine is not always absolutely essential; still, when we have to examine young people and children, its use is most certainly advisable. In the first place, the consequent dilatation of the pupil renders our examination so much easier; and secondly, atropine helps us to a more definite conclusion by thoroughly paralysing the accommodation; for although the examination takes place in a dark room, and with the patient looking into distance, it must be remembered

that there is often (especially in the case of children) some accommodation, due to the normal tone of the ciliary muscle, or to a condition of spasm common in hypermetropia and myopia—it also enables us easily to detect small degrees of astigmatism which frequently exist, and, but for this method, would probably escape notice. In mixed astigmatism the time that is saved by this plan is enormous.

To examine the patient, then, we dilate his pupils, and seat him in a dark room, with a lamp placed over his head, so far back that it throws no direct rays upon his face, and consequently requires no moving during the examination of either eye. Then the observer takes up a position about 120 cm. in front of the patient, and directing him to look at the perforation in the mirror, which should be a concave one and of 25 cm. focus, he will be enabled to reflect the light along the visual axis, and thus obtain the ordinary red fundus reflex.

If atropine has not been used, this procedure will cause the pupil so to contract, that it will be difficult to see the shadows, and in that case the observer must make the patient look a little inwards, so that the light may be reflected along the optic axis. If we now rotate the mirror slightly from side to side on its vertical axis, we see a shadow come out from behind the pupil, moving horizontally across the illuminated part. The edge of this shadow may be linear or somewhat crescentic; its direction may vary, being either vertical, or oblique if astigmatism exist. The shadow moves either in the same or the opposite

direction to the mirror, so that when the latter is tilted to the right, the shadow may come from the left, or *vice versâ.*

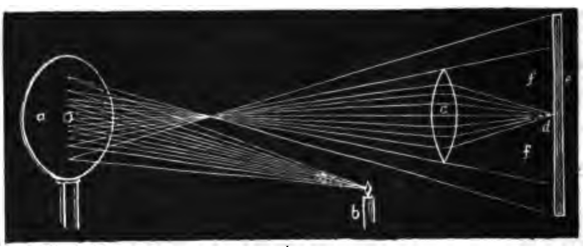
On the behaviour of these shadows the method retinoscopy depends.

Thus, assuming the shadow's edge to be vertical, if it move with the mirror, the case is one of myopia; but if it move against or in the opposite direction to the mirror, it is either one of hypermetropia, emmetropia, or low myopia.

What is this shadow whose edge we see? How and where is it formed? and what influences its movements and clearness?

To enable us to answer these questions we will place before a screen a convex lens, at such a distance from it that converging rays from a concave mirror, having crossed and become divergent, are brought to an exact focus, and there is then formed a very small, erect, well-defined image on the screen of the lamp, from

FIG. 47.

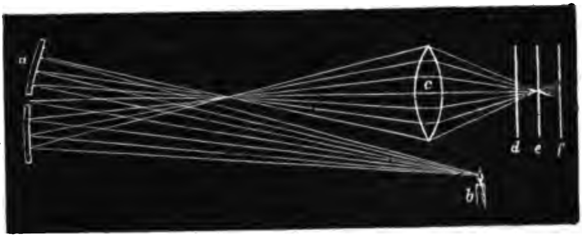


a. The concave mirror. *b.* The candle. *c.* The lens. *e.* The screen. *d.* Small image of candle formed on screen. *f.* Dense shadow around.

which the concave mirror received its rays; erect, because it has suffered two inversions.

This image of the lamp is surrounded by a sharply defined and dense shadow.

FIG. 48.



At *e* a small image of the candle is formed; at *d*, and *f*, circles of diffusion.

If we move the lens nearer to, or farther from the screen, the area of light becomes larger, and the illumination feebler, owing to the circles of diffusion on the screen.

FIG. 49.

M. The mirror. M′. The mirror after rotation. The extremities of the dotted line have moved in the opposite direction to the rotation of the mirror.

The mirror being rotated on its vertical axis, the image of the candle, with the surrounding shadow,

will always be found to move in the opposite direction to the mirror, whatever be the distance of the lens from the screen.

This is exactly what takes place in the eye, of which our screen and lens are a representation.

It may therefore be stated, that the illumination and shadows which we see, are an enlarged image of the lamp with the surrounding shadow, brought more or less to a focus on the retina according to the refraction of the eye. They always move against the mirror, but as these movements are seen through the transparent media of the eye, and thereby undergo refraction, the "apparent" may differ from the "real" movements. The image we see of the lamp, and its surrounding shadows, are formed in the same manner as all other images.

In emmetropia the image is formed at infinity thus, the rays which come from the two extremities A, B, emerge as two sets of parallel rays, in the same direc-

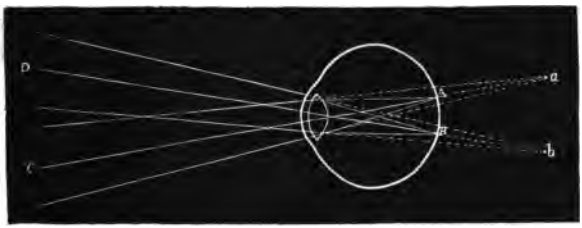
FIG. 50.

tion as the rays A C, B D; which, having passed through the nodal point, undergo no refraction. These two sets of rays soon diverge, leaving a space between

them, so that an observer, unless he be quite close to the observed eye, is unable to bring these rays to a focus on his retina; and, therefore, at a distance from the eye the observer sees only a diffused and blurred image.

In hypermetropia the image is formed behind the eye, thus, the rays from the two points, A, B, emerge from the eye in two sets of diverging rays, in the

FIG. 51.



same direction as the rays A C, B D, which undergo no refraction. These diverging rays have the appearance of coming from two points, *a*, *b*, behind the eye, where an erect image is formed, *a*, *b*.

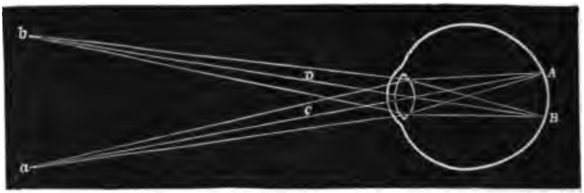
The more the rays diverge on exit, the sooner they will meet when prolonged backwards; and hence, the greater the hypermetropia, the nearer will the image be to the nodal point.

The observer, at a distance, sees a clear, erect image, which is formed behind the eye.

In myopia an inverted image is formed in the air in front of the eye, thus, the rays from the two points,

A, B, emerge as two converging sets of rays, which meet at *a*, *b*, on their secondary axis, thus forming an inverted image in front of the eye. This image can be distinctly seen by the observer, if he be at a suffi-

FIG. 52.



cient distance from the point, and accommodating for the particular spot at which the aërial image is formed.

We have already seen that the real movements of the shadows on the retina are against the mirror.

In hypermetropia the final image of the candle and its surrounding shadow, produced by the concave mirror, is an erect one formed behind the eye, and as it is viewed through the dioptric system of the eye, it therefore moves against the mirror.

In myopia the final image is an inverted one, projected forwards. This, therefore, moves with the mirror, it having undergone one more inversion.

To this rule, that in myopia the image moves with the mirror, there are two exceptions:

1st. If the observer be nearer the patient than his far point, but not within the focal distance of the mirror, the image will move against the mirror. This

is frequently the case in low degrees of myopia, where the patient's far point is beyond 120 cm.

2nd. If the observer be within the focal distance of the mirror, although beyond the far point of the patient, the image will in this case also move against the mirror. This latter source of error can always be avoided, by using a concave mirror of 25 cm. focus, and keeping 120 cm. from the patient.

Therefore, if the image move with the mirror, the case is certainly one of myopia. If it move against the mirror, it is most likely one of hypermetropia; but it may be emmetropia, or a low degree of myopia.

The movements tell us the form of ametropia we have to deal with. The extent of the movements on rotation of the mirror, the clearness of the image and the brightness of its edge, enable us to judge approximately the amount of ametropia to be corrected; some practice, however, is required before we can form an opinion with anything like accuracy.

The extent and rate of movement is always in inverse proportion to the ametropia; the greater the error of refraction, the less the movement, and the slower does it take place. This may be explained in the following way:

Suppose A to be the image of a luminous point formed on the retina, and that a line be drawn from A through the nodal point B to C. Now, if the case be one of myopia (Fig. 53), an inverted projected image of A is formed somewhere on this line, say at C. The higher the myopia, the nearer to the nodal point will

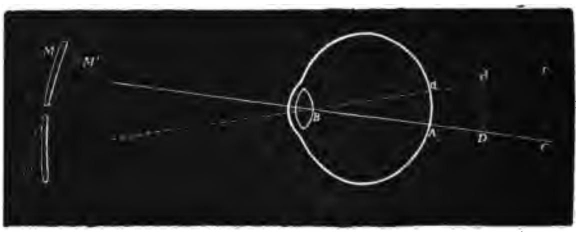
this image be; and hence we may suppose it formed as near as D. If the mirror be now rotated, so that it takes up the position of the dotted line M′, C will have

FIG. 53.

moved to *c*, and D to *d*; whence it is clear, that C has made a greater movement than D.

Had the case been one of hypermetropia (Fig. 54), the image would have been projected backwards, and,

FIG. 54.



as in myopia, the higher the degree of hypermetropia, the nearer to the nodal point is the image formed.

In this case, the line from the nodal point B to A is prolonged backwards, and the image of the luminous point in a low degree of hypermetropia is formed,

say at C, and in a higher degree, say at D. On moving the mirror into the position of the dotted line M′; C moves to *c* and D to *d*; whence it is clear that C has made a greater movement than D.

Therefore, as the ametropia increases, the extent of the movement of the image decreases. The clearness of the image and the brightness of its edge decrease, as the ametropia increases.

As shown in Fig. 47, it was stated that on placing before a screen a convex lens, at such a distance that converging rays from a concave mirror, having crossed and become diverging, are brought to an exact focus, there is then formed a very small, erect, well-defined image on the screen of the lamp from which the concave mirror received its rays. On moving the lens nearer to or farther from the screen, the larger becomes the area of light, and the feebler the illumination, owing to the circles of diffusion formed on the screen.

Therefore, in the case of the eye, the greater the ametropia, the larger is the circle of diffusion and the weaker the illumination, so that the image we see, is less bright and its edge less distinct.

It is, therefore, in the lower degrees of ametropia that we get the brightest and best-defined shadows; and when we thus see them, we may assume that we are approaching the stage of correction.

In myopia and hypermetropia of high degrees, the shadow becomes more or less crescentic in shape, instead of linear, due to the shape of the circle of diffusion formed on the retina.

Having thus answered the questions concerning the shadows which we see in retinoscopy, we are in a position to pursue further the practical working of the subject, with special reference to the correction of any existing error of refraction by glasses.

The patient, then, being seated in the dark room, the pupils dilated, and the lamp over his head, as before described, we take up our position 120 cm. in front, with a concave mirror of 25 cm. focus (a Galezowski mirror is the one commonly used, and is found convenient). The patient is then directed to look at the centre of the mirror, so that the light from the lamp may be reflected along the visual axis. On looking through the perforation of the mirror, we get the ordinary fundus reflex, bright if the patient be emmetropic, less so if he be ametropic, and the greater the ametropia, the less bright will the fundus reflex be. We now rotate the mirror on its vertical axis to the right. If a vertical shadow come across the pupil from the patient's right, *i.e.* in the same direction as the movement of the mirror, or what is the same thing, if the shadow move in the same direction as the circle of light on the patient's face, the case is one of myopia. Should the edge of the image appear well defined and move quickly, in addition to a bright fundus reflex, we infer that the myopia is of low degree and proceed to correct it.

Each eye must of course be tried separately.

The patient having put on a pair of trial spectacle-frames, we place a weak concave glass, say -1 D., before the eye we are about to correct. If the image

still move with the mirror, we place in the frame −1·5 D., then −2 D., and so on, until we find the point at which no distinct shadow can be seen. Supposing this to be −2 D., and that on trying −2·5 D. the image move against the mirror, −2 D. is assumed to be the correcting-glass. This, however, will be found not to be the full correction of the myopia, because, being situated at 120 cm. from the patient, when his far point approaches that distance, we are unable to distinguish the movements of the shadow; and when the far point of the observed, though not situated at infinity, is still at a greater distance than the observer, we get a shadow moving in the opposite direction. Hence it is customary in cases of myopia to add on −·5 D. to the correcting-glass, and this would give us −2·5 D. as the proper glass for our case.

In correcting myopia, it is a convenient and reliable plan, to stop at the weakest concave glass which makes the image move against the mirror, and put that down as the correcting-glass.

When the myopia is of high degree and a strong concave glass has to be used for its correction, the light reflected from the mirror is so spread out by the concave glass, that fewer rays pass into the eye, and therefore the illumination is not so good as in other states of refraction.

Had we obtained a reverse shadow, we should then try convex glasses, which, if +·5 D. neutralized, we should assume the case to have been one of low myopia. Had it required +1 D., then it would be one of emme-

tropia; above this, hypermetropia. We proceed exactly as before, putting up stronger and stronger glasses, until we are unable to make out the movements of the image. This is assumed to be the correcting-glass, and, just as in the above case the myopia was under-corrected, so in this, the hypermetropia is slightly over-corrected; and hence it is usual to deduct from this glass +1 D., or we may stop at the strongest convex glass with which we still get a reverse shadow.

To sum up, therefore, if the shadow move with the mirror, it is a case of "myopia;" if against, it may be weak myopia if +·5. D. cause the image to move with the mirror; emmetropia if +1 D. neutralized it; hypermetropia if a stronger glass is required.

The points to be observed, are—(1) the direction of the movement of the image, as indicating the kind of ametropia: (2) the rate and amount of movement, (3) the brightness of the edge of the image, (4) and the amount of fundus reflex all indicate the degree of ametropia.

We have taken notice only of the horizontal axis, but any other meridian will, of course, do equally well, if the case be one of hypermetropia or myopia simply. If, however, the case be one of astigmatism, then the axes are different.

In astigmatism, the flame of the candle on the retina, instead of being, as in emmetropia, a small well-defined image, or as in myopia or hypermetropia, a circle of diffusion, is distorted so as to be more or less of an oval form, according to the position of the

retina and the maximum and medium curvatures of the cornea.

In the normal eye, the focus of the virtual meridian of the cornea, is slightly shorter than that of the horizontal. So long as no impairment of vision occurs, the eye is said to be normal. When, however, the acuteness of vision is diminished, then astigmatism is said to exist.

Parallel rays, passing through a convex spherical lens, disregarding some slight irregularities due to aberration, form a cone, any section of which, perpendicular to its axis, will be a circle. The size of the circle depends upon the distance of the point at which the lens is from its focus. If beyond the focus the cone be divided, as in myopia, the rays having crossed and become divergent, a circle of diffusion is formed on the retina. In hypermetropia the cone is divided before having come to a focus, and thus forms a diffusion circle. But in astigmatism the divided cone is circular only at one point, No. 4 in Figs. 68 and 69. To explain this, we place in front of the convex spherical glass, a weak convex cylindrical glass, with its axis horizontal. The result of this is, that parallel rays passing through this combination do not form a circular cone, because the rays which pass through the vertical meridian, come to a focus before those passing through the horizontal, as shown in Fig. 68.

The rays being divided at 1, an oblate oval is formed; at 2 a horizontal straight line, the vertical rays having come to a focus; at 3, 4, 5 the vertical

rays have crossed and are diverging, and the horizontal rays are approaching; at 4, a circle is formed; at 6, a vertical straight line, the horizontal rays having met and the vertical still diverging; a large prolate ellipse is formed at 7.

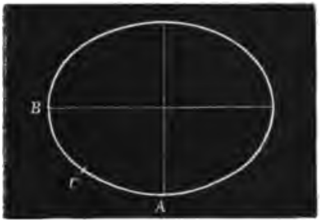
So that in astigmatism, the image of the retina is more or less of an oval, instead of being either a small well-defined image of the candle, or a circle of diffusion, according to whether the eye be emmetropic, myopic, or hypermetropic. This oval may have its horizontal and vertical edges, corresponding to the horizontal and vertical meridians of the cornea. Frequently, however, they have an intermediate position, which, as will be presently shown, is the cause of the oblique shadows in cases of astigmatism.

The image of this oval is formed by the dioptric apparatus of the eye in the same way as all other images are formed, as has been ably explained by my friend Mr Charnley, in a paper by him in the 'Royal London Ophthalmic Hospital Reports' for August, 1882. Thus:

"Suppose the retina of the eye to be so situated (1 in Fig. 68) that the cone of light passing through the pupil makes an oblate oval, then rays proceeding from any point (A) on the horizontal edge, after refraction through the unequally curved meridians of the astigmatic eye, converge to, or diverge from, not a point, but two straight lines. The image of the edge will be referred to the position where the image of adjacent points on the edge are drawn out into ovals, whose long axes are horizontal, and therefore

overlap, and so cause the greatest condensation of rays. Now, this position is at the far point of the

FIG. 55 (*Charnley*).



vertical meridian, where, indeed, the image of A and adjacent points are ovals, so elongated that they may be considered as horizontal straight lines,

"The position of the image of the horizontal edge of the retinal image depends, then, on the refraction of the vertical meridian of the eye, and is in front of, behind the eye, or at infinity, according as the eye is myopic, hypermetropic, or emmetropic. The horizontal edge, then, of the retinal image, and the vertical meridian of the astigmatic eye, stand then in the same relation as the whole image and any meridian in the spherical eye.

"The image of the vertical edge of the oval retinal image, depends on the refractive condition of the horizontal meridian of the eye.

"Of the part of the edge of the oval near C, intermediate between A and B, we get no distinct image formed, because the images of adjacent points are ovals, whose long axes are either horizontal or vertical,

whilst these adjacent points are arranged neither horizontally nor vertically with respect to one another. Hence we have only two distinct shadows, which are perpendicular to the principal meridians of refraction —that is, horizontal and vertical."

The meridians have been assumed to be horizontal and vertical: frequently they are so, but often they are more or less oblique, and then the shadows, being at right angles to the chief meridians, are also oblique, and so also will the movements be.

The oblique movements of the shadow, are independent of the direction in which the mirror is rotated.

This obliquity is produced thus: (Fig. 56) if behind a circular opening, which is to represent the pupil, we place obliquely an oval piece of card, which is to re-

FIG. 56.

present the image on the retina, so that that part of its edge, which occupies with regard to the circular opening an oblique position; on moving the card across in the direction O D, it has the appearance of moving in the direction C O, at right angles to the edge of the card.

Hence the direction of the shadow's movement is deceiving, and its oblique edge is due to the shape of the image, and not to the direction in which the movements of the mirror are made. Therefore the apparent movements are always at right angles to the edge of the shadow.

The same takes place in astigmatism, the two chief meridians of which, are parallel and perpendicular to the shadows. In using retinoscopy, therefore, when the edge of the image is oblique, we know at once that the case is one of astigmatism. If, however, it should be horizontal or vertical, we judge, if one shadow be more distinct or quicker in its movements than the other, though we are not always able to say at once, that astigmatism exists. We therefore proceeded to correct one meridian. If the shadow move against in all meridians, we first take the vertical, and put up in front of the patient, in a spectacle-frame, convex spherical glasses, until we find the *strongest* with which the shadow still moves against the mirror. We put this down as the correcting-glass for this meridian, and let us suppose that glass to be + 2 D. We next take notice of the horizontal meridian, and if + 2 D. is also the highest glass with which we still get a reverse shadow, then of course we know the case is one of simple hypermetropia. But supposing the highest convex glass had been + 4 D., we indicate it conveniently thus:

$$\begin{array}{r|l} & +2\text{ D.} \\ \leftarrow & -+4\text{ D.} \end{array}$$

The case is one of compound hypermetropic astigma-

tism, and should require for its correction + 2 D. spherical combined with + 2 D. cylinder axis vertical.

We will take another case—that in which the vertical meridian requires − 2 D. to give a reverse shadow, and the horizontal + 2 D., this being the highest glass with which we still obtain a reverse shadow. Here we have a case of mixed astigmatism which can be corrected in either of the three following ways:

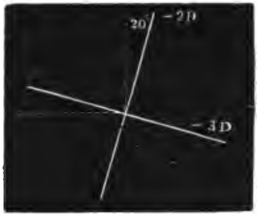
1st. − 2 D. cylinder axis horizontal combined with + 2 D. cylinder axis vertical; this is a plan seldom used, and is not so easy to work with as a sphere and a cylinder.

2nd. − 2 D. sphere combined with + 4 D. cylinder axis vertical, or

3rd. + 2 D. sphere combined with − 4 D. cylinder axis horizontal. This last is perhaps the preferable plan. Opticians like working − cylinders on to + spheres, rather than + cylinders upon − spheres.

Supposing the axis of the shadow to be oblique, we know at once that astigmatism exists, and we proceed to correct each meridian separately, moving the mirror at right angles to the edge of the shadow, not horizontally and vertically. We judge of the amount of obliquity by the eye, and can frequently tell within a few degrees. If the vertical meridian be 20° out of the vertical, and require for its correction − 2 D., and the axis at right angles to this (which will be therefore at 110°) require − 3 D. we express it as Fig. 57, and correct it with sphere − 2 D. combined

FIG. 57.



with cylinder — 1 D. axis 20°, the case being one of compound myopic astigmatism.

Often one is able to put up the cylinder in the spectacle frame with the exact degree of obliquity.

Having found the glasses which correct the two meridians, we put up the combination in a spectacle trial frame, and if we now get only a slightly reversed shadow in every direction, the glasses are assumed to be the right ones, and we proceed to confirm it by trying the patient at the distant type, making any slight alterations that may be necessary.

I cannot too strongly recommend the use of a solution of atropine, gr. iv to ℥j, frequently dropped into the eyes for three days prior to the examination, so as thoroughly to relax the accommodation. It can be used without fear, and without a great amount of inconvenience in most young people under twenty years of age. I have worked out a great many cases of astigmatism, and feel more and more the necessity of using this drug to enable one to arrive at exact results. I might almost say that I have never seen a young person whose astigmatism has been worked out with-

out atropine wearing the right correction; and the inconvenience entailed upon the patient for two weeks by its use, is not to be compared to the trouble and asthenopia from which he or she is so liable to suffer, if the glasses worn are not the proper ones.

In old persons with small pupils, in whom it is difficult to see the movements of the shadow, and in whom solutions of atropine of the ordinary strength are dangerous, on account of the occasional occurrence of that much dreaded disease "glaucoma," which has been clearly traceable to its use, I have often found it convenient to dilate the pupil with homatropine in solution, gr. ij to ℥j of water, or with an exceedingly weak solution of atropine $\frac{1}{40}$ gr. to ℥j of water.

I will now briefly describe two modifications of retinoscopy which have been suggested and carried out.

First, Mr. Story has proposed the use of a plane mirror, in the place of the concave one already described, it certainly possesses several advantages and is preferred by many surgeons.

With it the movements of the shadow are in the same direction as those of the disc and blood-vessels, as seen by the direct ophthalmoscope at a distance from the eye (page 60), viz. in the same direction as the observer's movements in hypermetropia, and in the opposite direction in myopia.

No additions or subtractions have to be made to the glass found by this method.

The disadvantage is, the distance at which the observer must work, viz. 4·5 metres from his patient.

The second modification of retinoscopy has been proposed by Dr. Jackson, of Philadelphia, who uses a plane mirror, and thus describes the practical application of this modification in the various states of refraction.

"*Simple myopia.*—Rays of light from any given point of the retina emerge from the myopic eye convergent, and meet at the point in front of the eye, for which the eye is optically adjusted. The accommodation being in abeyance, this will be the far point of distinct vision, So that there is formed at the far point of the myopic eye an inverted image of the retina. If now the eye of the observer be placed between the patient's eye and its far point, there will be seen an erect image of the patient's retina; but if the observer view the patients's eye from somewhere beyond its far point, he will see, not an erect image, but the inverted image formed at that far point. In the first case the boundary of light and shade which marks the border of the retinal area will appear to move with the facial area; in the second case, against it. In practice the surgeon begins the examination somewhat more distant from the patient than the far point of the eye under examination. Then he slowly approaches the patient, all the while watching the apparent movement of the retinal area produced by slightly rotating the mirror from side to side about its axis. As long as this apparent movement is opposed to that of the facial area, the surgeon knows he is watching the inverted image at the patient's far point. Presently, however, the direction of the movement of

the retinal area cannot be distinguished, the far point has now been reached; and coming still closer the apparent movement again becomes distinct, but is seen to correspond in direction with the real movement, the far point has now been passed, and the patient's retina is being viewed in the erect image. By noting the point at which this reversal occurs, the surgeon notes the far point of the eye under observation; by measuring the distance from this point of reversal to the eye, he measures the distance from the patient to his far point of distinct vision; and the reciprocal of this distance, of course, expresses the degree of his myopia. Thus, supposing the point of reversal to be one-fourth of a metre in front of the eye, one divided by one-fourth equals four, the number of dioptres of myopia present.

"Theoretically, the method as now described is complete, but for convenience and accuracy in its application, one or two other points must be attended to. When the observer's eye has come quite close to the patient's, say to within one-eighth of a metre, and the inverted image is still seen between them, it is best to place a concave lens (—8 D.) before the patient's eye, and then to estimate the amount of myopia remaining uncorrected; and by adding it to the amount which the lens used has corrected, determining the total myopia present. When the observer has approached so near the inverted image that it lies closer to his eye than his near point of distinct vision, he can no longer see that image distinctly. Still he can distinguish in which direction the retinal area appears

to move, until he approaches somewhat nearer to the image, when the circles of diffusion upon his own retina become so large that the retinal area of light, seen in the patient's pupil, seems very diffuse and faint, and the direction of its apparent movement uncertain. Because of this, there is great practical difficulty in determining exactly where the point of reversal is situated. Now it is evident that if the point of reversal is within a few inches of the eye, an error of two or three inches as to its position entails an error of some dioptres in the amount of myopia present. Therefore, when by the method above described the degree of myopia has been approximately ascertained, place before the patient's eye a concave lens strong enough to remove the point of reversal a metre or more from the eye. At such a distance, an error of two or three inches as to the position of the point of reversal is of no consequence; and an accurate determination of the remaining, and hence of the total myopia, can readily be made. Having determined the amount of myopia present, the surgeon will of course be guided by the rules he would follow had the myopia been measured by any other method.

"*Hypermetropia.*—On viewing the fundus reflex it is found that at all distances the erect image is seen, and the retinal area appears to move with the facial area. Place before the patient's eye a convex lens strong enough to over-correct the hypermetropia. Then, by the method given above, determine the degree of myopia so produced. Deduct this amount of myopia from the strength of the convex lens used; and the

remainder will express the degree of hypermetropia present. Suppose, for example, the hypermetropia amounts to four dioptres. Placing a five dioptre convex lens before the eye, it is found that one dioptre of myopia is produced, the point of reversal being at one metre. Then five, minus one, equals four, which expresses in dioptres the amount of hypermetropia present. Should it be found that the + 5 . D. lens leaves the eye hypermetropic so that the erect image is seen at all distances, replace it by a + 10 . D., and proceed as before. As in myopia, however, the final accurate determination should be made at a distance of not less than one metre. It may be noticed that low degrees of myopia may be measured without the use of any lens, but that to determine the degree of hypermetropia present, a convex lens is always necessary.

"*Emmetropia* is determined by the method for measuring hypermetropia. The convex lens being placed before the eye, the resulting myopia is found to equal exactly the strength of the lens in use.

"*Regular Astigmatism.*—In applying the test to the measurement of regular astigmatism, instead of rotating the mirror about any axis, vertical, horizontal, or oblique, as may be done when the curvature of the cornea is the same in all directions, it is rotated about axes perpendicular to the directions of the principal meridians of curvature, and the point of reversal thus found for each principal meridian. To determine the direction of these principal meridians, the eye, if not previously so, should be rendered myopic in all meridians, and then viewed from different distances. It

will then be found that at certain points the fundus reflex takes the shape of a more or less distinct band of light stretching across the pupil, while on one or both sides of it may be seen a shaded area 'the somewhat linear shadow' of Bowman. This band of light is very readily moved in a direction perpendicular to its length, but in the direction of its length cannot be made to move at all. The point where this appearance is presented is the point of reversal for that principal meridian of the cornea, whose direction coincides with the length of the band. The other principal meridian is, of course, at right angles to this; and the observer by placing his eye at its point of reversal will be in position to see a similar band extending in a direction perpendicular to that of the band first observed. This use of the shadow-test may be made clearer by the consideration of what occurs in a particular case. Suppose the patient's cornea to have such a curvature as to cause in the horizontal meridian (axis vertical) a hypermetropia of four dioptres, and in the vertical meridian (axis horizontal) a myopia of one dioptre. Place before the eye a + 5 . D. spherical lens. On approaching it from a distance, it is found that the retinal area moves against the facial area in all directions. But as the distance of one metre is approached, it is noticed that the retinal area takes the form of a horizontal band, readily moveable upward or downward, but difficult to move to the right or left; and when the point of one metre is reached, all movement to the right or left ceases, and the band is more distinct. Going still closer, the point of reversal for the horizontal

meridian being passed, movement to the right or left reappears, but it is now with the facial area. The movement upward or downward is still against that of the facial area. As the patient is still approached, the appearance of a horizontal band fades out, and presently is replaced by that of a vertical band. The vertical band moves readily to the right or left, but less distinctly upward or downward, and at one-sixth of a metre all vertical motion is lost. This is the point of reversal for the vertical meridian. On approaching still closer, vertical movement reappears, but like the horizontal movement it is now with the facial area, not against it. Thus it is found that for the horizontal meridian the point of reversal is one metre distant from the eye, and that for the vertical meridian the point of reversal is one-sixth metre distant. That is, the use of the convex lens has made the eye myopic in the one meridian one dioptre, in the other meridian six dioptres; and by taking into account the effect of the spherical lens used, the mixed astigmatism is seen to be what we supposed it. But for accurate work, as in simple myopia and hypermetropia, the degree of ametropia for each meridian should be finally determined with such a lens before the eye as would place the point of reversal, for that meridian, one metre or more distant."

A few cases from my note-book will help to make the subject clear.

Case 1.—Boy, aged 11 years.

$$\text{R.V. } \tfrac{6}{12} - 1\text{ D.} = \tfrac{6}{6}$$
$$\text{L.V. } \tfrac{6}{18} - 1\text{ D.} = \tfrac{6}{6}$$

Bright fundus reflex, shadow moves with the mirror, but with — ·5 D. a reverse shadow is seen. The case, therefore, looks like one of weak myopia. Ordered guttæ atropiæ gr. iv to ℥j, three times a day; on the third day, with retinoscopy, + 1 D. still gives an opposite shadow. On trying the patient at the distant type with + 1 D. both eyes read $\frac{6}{6}$ well. This, therefore, was a case of hypermetropia simulating weak myopia, due to ciliary spasm: such cases are not rare.

Case 2.—Girl, aged 13, suffering from "tinea tarsi."

R.V. $\frac{6}{6}$ Hm. 1 D. = $\frac{6}{6}$
L.V. $\frac{6}{6}$ Hm. 1 D. = $\frac{6}{6}$

Guttæ atrop., gr. iv to ℥j. Fundus reflex, moderate; a reverse shadow is seen moving somewhat slowly. On trying + 2 D. shadows become much more distinct and the movements quicker; + 4 D. is found to be the strongest glass with which we still get a reverse shadow. With + 4 D. $\frac{6}{6}$ was read, but with no stronger glass, this therefore is the measure of the patient's total hypermetropia.

Case 3.—Young man, aged 20.

R.V. $\frac{6}{24}$ Hm. 4 D. = $\frac{6}{9}$
L.V. $\frac{6}{24}$ Hm. 4 D. = $\frac{6}{12}$

Under atropine; right eye at distant type sees only $\frac{6}{60}$. Fundus reflex very dull, movements of shadow slow and against the mirror. On putting up + 5 D. the reflex is much brighter, the edge of shadow distinct and its movements quicker. We try + 6, 7, 8, 9, and the last gives a shadow moving with the mirror. + 8 D. is the highest, which still leaves the shadow moving against. On trying the eye at the distant type

$\frac{6}{9}$ and 4 letters of $\frac{6}{6}$ are at once read. No alteration in the glass improves sight.

Left eye. Fundus reflex, and movements as in right. We commence by trying + 8 D. which we found the other eye required. In the vertical meridian the movement is against the mirror, while + 9 D. causes it to move with it. In the horizontal meridian with + 8 D. the shadow moves with the mirror, and + 7 D. causes it to move against. We express it thus—

$$\text{—}\Big|\begin{array}{l}+8\ \text{D.}\\ \text{—}+7\ \text{D.}\end{array}$$

and on trying the combination at the distant type,

$$\frac{+7\ \text{D. sp.}}{+1\ \text{D. cylinder axis horizontal,}}$$

the patient is able to read $\frac{6}{9}$; and on decreasing the sphere from 7 D. to 6·5 D., $\frac{6}{6}$ is read, so that the proper correction for this eye is,

$$\frac{+6{\cdot}5\ \text{D. sp.}}{+1\ \text{D. cy. axis horizontal;}}$$

in this case, therefore, hypermetropia was present in one eye, compound hypermetropic astigmatism in the other.

Case 4.—Young woman, aged 17, sees with either eye $\frac{6}{24}$ -1 D. = $\frac{6}{18}$. Retinoscopy without atropine—

$$\text{R.}\ \text{—}\Big|\begin{array}{l}-3{\cdot}5\ \text{D.}\\ \text{—}-1\ \text{D.}\end{array} \qquad \text{L.}\ \times\ \begin{array}{l}-2\ \text{D.}\\ +1\ \text{D.}\end{array}$$

Ordered guttæ atrop., gr. iv to ℥j, for three days; then with retinoscopy the result is—

$$\text{R.}\ \text{—}\Big|\begin{array}{l}-2{\cdot}5\ \text{D.}\\ \text{—Em.}\end{array} = \text{cy. } 2{\cdot}5 \text{ axis horizontal, reads } \tfrac{6}{6}.$$

$$\text{L.}\ \times\ \begin{array}{l}-2\cdot\ \text{D.}\\ +1\ \text{D.}\end{array} = \frac{+1\ \text{D. sp.}}{-3\ \text{D. cy. axis } 180^\circ} \text{ reads } \tfrac{6}{9}.$$

After recovering from atropine the result was confirmed and the following correction ordered to be worn constantly.

$$\text{R.}\frac{-1\text{ D. sp.}}{-2{\cdot}5\text{ D. cy. axis horizontal.}}$$
$$\text{L.} -3\text{ D. cy. axis }180^{\circ}.$$

Case 5.—Mary E—, aged 15, pupil teacher, brought up from Cardiff about her eyes; suffers much from headache and pain in eyes, especially the right, during the evenings. Has tried many opticians to get spectacles to suit her, but has always been unable to do so. R. $\frac{6}{36}$ slightly improved with $-$ 1 D. L. $\frac{6}{36}$ also slightly improved with $-$ 1 D. On placing the patient in the dark room, retinoscopy at once shows the case to be one of mixed astigmatism, and the chief meridians horizontal and vertical; we proceed to correct each meridian, and the result is—

R. —|— +1 D. (vertical: −5 D.)   L. —|— +1·5 D. (vertical: −5 D.)

On trying this combination before the right eye, $\frac{6}{12}$ is read. We express the vision of right eye thus—

$$\text{R. } \tfrac{6}{36} + 1\text{ D. sp.} \bigcirc -6\text{ D. cy. axis horizontal} = \tfrac{6}{12}.$$

With the left eye the combination gives, with the cylinder not quite horizontal, but slightly outwards and downwards, $\frac{6}{9}$.

$$\text{L. } \tfrac{6}{36} + 1{\cdot}5\text{ D. sp.} \bigcirc -6\cdot\text{ D. cy. axis }170^{\circ} = \tfrac{6}{9}.$$

The patient remarked that she had never seen things so clearly before. This result was very satisfactory, and was arrived at in about ten minutes, thus sparing one's self an infinite amount of time and trouble, which

would have been required to work out such a case by any of the older methods. As is my usual practice in cases of astigmatism, I ordered guttæ atrop., gr. iv to ℥j, three times a day for four days, when the result was—

$$\text{R.}\ \begin{array}{c|l} & -4\text{ D.} \\ \hline & +2\text{ D.} \end{array} \qquad \text{L.}\ \begin{array}{c|l} & -4\text{ D.} \\ \hline & +2\text{ D.} \end{array}$$

R.V. $\frac{6}{60}$ + 2 D. sp. ⊂⊃ − 6 D. cy. axis 175° = $\frac{6}{9}$.
L.V. $\frac{6}{60}$ + 2 D. sp. ⊂⊃ − 6 D. cy. axis 170° = $\frac{6}{9}$.

In this case the glasses were again tried after atropine was recovered from, and the following glasses ordered, which were of course to be worn constantly:

$$\text{R.}\ \frac{+1\text{ D. sp.}}{-6\text{ D. cy. axis }175^\circ.} \qquad \text{L.}\ \frac{+1{\cdot}5\text{ D. sp.}}{-5{\cdot}5\text{ D. cy. axis }170^\circ.}$$

Case 6. *Mixed Astigmatism.*—Mr. C—, aged 24, has noticed that for the past few years, the eyes become very tired at night, especially when much writing or reading has been done, he thinks he sees distant objects less clearly than formerly.

R. V. $\frac{6}{24}$ not improved with convex or concave glasses; with pin-hole test $\frac{6}{12}$.

L. V. $\frac{6}{18}$ not improved with convex or concave glasses; with pin-hole test $\frac{6}{12}$.

After using atropine for four days, retinoscopy gave the following results:

$$\text{R.}\ \begin{array}{c|l} & +3\text{ D.} \\ \hline & +{\cdot}5\text{ D.} \end{array} \qquad \text{L.}\ \begin{array}{c|l} & +2{\cdot}5\text{ D.} \\ \hline & +{\cdot}5\text{ D.} \end{array}$$

$$\text{R.}\ \frac{+{\cdot}5\text{ D. sp.}}{+2{\cdot}5\text{ D. cy. axis }160^\circ} = \tfrac{6}{6}. \qquad \text{L.}\ \frac{+{\cdot}5\text{ D. sp.}}{+1{\cdot}5\text{ D. cy. axis }165^\circ} = \tfrac{6}{6}.$$

We direct the patient to return after the effects of the atropine have passed off, which he does in ten

days; we then try our correction, deducting + 1 D. sphere for the atropine.

$$\text{R.}\frac{-\cdot5\ \text{D. sp.}}{+2\cdot5\ \text{D. cy.}}\ \text{axis}\ 160^\circ=\tfrac{6}{6}. \qquad \text{L.}\frac{-\cdot5\ \text{D. sp.}}{+1.5\ \text{D. cy.}}\ \text{axis}\ 165^\circ=\tfrac{6}{6}.$$

This correction was accordingly ordered to be worn constantly.

Case 7. *Mixed Astigmatism.*—Sarah K—, aged 21, complains that her eyes have of late been very painful, and she has also suffered much from headaches, which have sometimes ended with an attack of sickness.

$$\text{R.V.}\ \tfrac{6}{18}-1\ \text{D.}=\tfrac{6}{12}. \qquad \text{L.V.}\ \tfrac{6}{24}-2\ \text{D.}=\tfrac{6}{18}.$$

After atropine. Retinoscopy gave

R. — | − 1·25 D. / — + 1 D.   L. ╳ + 1 D. / − 3·5 D.

$$\text{R.}\frac{+1\ \text{D. sp.}}{-2\cdot25\ \text{D. cy.}}\ \text{axis horiz.}=\tfrac{6}{6}. \qquad \text{L.}\frac{+1\ \text{D. sp.}}{-4\ \text{D. cy.}}\ \text{axis}\ 125^\circ=\tfrac{6}{9}.$$

After the effects of atropine had passed off the correction which gave the best results was—

$$\text{R.}-2\cdot25\ \text{D. cy. axis horiz.}=\tfrac{6}{6}. \qquad \text{L.}\frac{+\cdot25\ \text{D. sp.}}{-4\ \text{D. cy.}}\ \text{axis}\ 125^\circ=\tfrac{6}{9}.$$

These spectacles were ordered to be worn constantly.

Case 8. *Simple Hypermetropic Astigmatism.*—Jane Q—, aged 11, has always seen near objects badly, she turns her head to one side, so as to look out of the corners of her eyes.

R. V. $\frac{6}{24}$ not improved with spheres, with pin hole $\frac{6}{18}$.
L. V. $\frac{6}{24}$ not improved with spheros, with pin hole $\frac{6}{18}$.
Retinoscopy after atropine gives

R. — | + 1 D. / — + 5 D.   L. — | + ·75 D. / — + 4 D.

R. $\dfrac{+1\text{ D. sp.}}{+4\text{ D. cy. axis vert.}} = \frac{6}{12}$. L. $\dfrac{+\cdot 75\text{ D. sp.}}{+3\cdot 5\text{ D. cy. axis vert.}} = \frac{6}{12}$.

After the atropine had passed off.

R. + 4 D. cy. axis vert. = $\frac{6}{12}$. L. + 3·5 D. cy. axis. vert. = $\frac{6}{12}$.

Spectacles of this strength were ordered for constant use.

Case 9. *Simple Myopic Astigmatism.*—Thomas I—, aged 20, sees rather badly both near and distant objects.

R. V. $\frac{6}{12}$ not improved.

L. V. $\frac{6}{12}$ not improved.

After atropine had been used for a week, retinoscopy gave—

R. $\begin{array}{c|l} & +1\text{ D.} \\ \hline & \text{Em.} \end{array}$ L. $\begin{array}{c|l} & +1\text{ D.} \\ \hline & \text{Em.} \end{array}$

R. + 1 D. cy. axis horiz. = $\frac{6}{6}$. L. + 1 D. cy. axis horiz. = $\frac{6}{6}$.

After atropine has passed off.

R. – 1 D. cy. axis vert. = $\frac{6}{6}$. L. – 1 D. cy. axis vert. = $\frac{6}{6}$.

This correction was ordered for constant use.

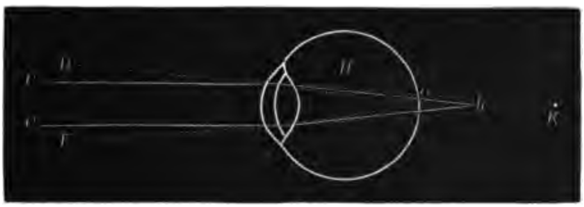
In all cases before ordering spectacles, the effect of the atropine must be allowed to pass off and the result confirmed, which can usually be done in about a week or ten days; it is then frequently found that the spherical glass, in cases of hypermetropia and hypermetropic astigmatism, requires slightly diminishing, usually about 1 D., owing to the tone of the ciliary muscle. In myopia and myopic astigmatism, the spherical glass has to be slightly increased for the same reason.

CHAPTER V

Hypermetropia

Hypermetropia (H) (Ὑπὲρ, in excess; μέτρον, measure; and ὤψ, the eye) may be defined as a condition in which the antero-posterior axis of the eyeball is so short, or the refracting power so low, that parallel rays are brought to a focus behind the retina (the accommodation being at rest). In other words, the focal length of the refracting media is greater than the length of the eyeball.

Fig. 58.



Parallel rays focus at *b* behind the retina; those coming from the retina emerge as diverging rays.

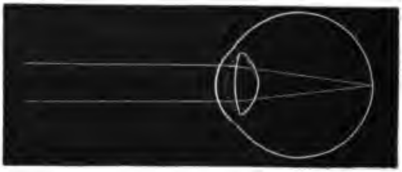
In the passive hypermetropic eye, therefore, parallel rays C and G come to a focus behind the retina at *b*,

forming on it at *a*, a circle of diffusion instead of a point. Rays coming from the retina of such an eye, emerge having a divergent direction (D and E); these, if prolonged backwards, will meet at a point (K) which is the punctum remotum, and being situated behind the eye it is called negative.

The distance of the punctum remotum behind the eye will equal the focus of the convex lens which corrects the hypermetropia; thus, supposing it situated 20 cm. behind the retina ($\frac{100}{20} = 5$), 5 D. will be the convex glass which will render parallel rays so convergent that they will focus on the retina, or cause rays from the retina to be parallel after passing through it; allowance must be made for the distance between the cornea and the convex lens.

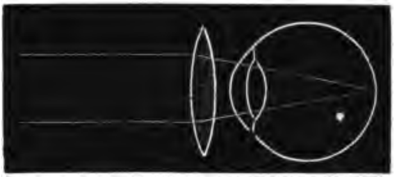
The hypermetropic eye at rest, is only able to bring *convergent* rays to a focus on the retina. All rays in nature are divergent, some so slightly so, that when coming from a distant object, they are assumed to be parallel. Rays can only be made convergent by means of accommodation, or by a convex lens held in front of the eye.

FIG. 59.



Parallel rays focussed on retina by accommodation. The dotted line shows the lens more convex as a result of the contraction of the ciliary muscle.

FIG. 60.



Parallel rays rendered so convergent by passing through a convex lens that they focus on the retina.

Therefore a hypermetrope with relaxed accommodation, sees all objects indistinctly. So that such a person having to use some of his accommodation for distance, starts with a deficit for all other requirements, equal to the amount of hypermetropia.

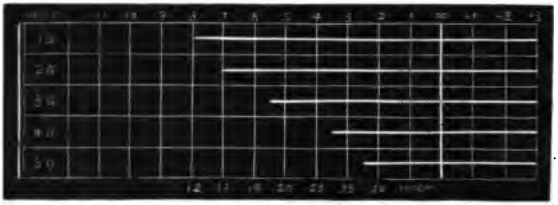
Thus, supposing an individual, hypermetropic to the extent of 4 dioptres, and possessing 6 D. of accommodation, he will by the exercise of this power to the extent of 4 D., be able to bring parallel rays to a focus on the retina, and so see distant objects clearly, this leaves him 2 D. of accommodation for near objects; which will bring his near point to 50 cm., a distance at which he will be unable to do near work.

Besides, it must be remembered, that only a part of the accommodation can be used for sustained vision, fatigue soon resulting when the whole of the accommodation is put in force.

The following diagram is intended to show by the number of spaces, each representing a dioptre, through which the thick lines are drawn, the amount of accommodation in a hypermetrope of 3 D., at different ages as given on the left of the diagram. The figures

FIG. 61.

Dioptres.



above, indicate the number of dioptres, and those below, the near point for each increasing dioptre of accommodation.

The amount of hypermetropia is calculated and expressed, by that convex glass which makes parallel rays so convergent, that they meet on the rods and cones of the retina, the accommodation being suspended.

The commonest amount of error is about 2 D. Small degrees may require some trouble to discover, and can only possibly be found out, after the eye has been atropized.

Hypermetropia is divided into *latent* and *manifest*. The manifest, Donders subdivides into *absolute*, *relative*, and *facultative* :

Absolute, when by the strongest convergence of the visual lines accommodation for parallel rays is not attained, in other words, when distant vision is impaired; this variety is seldom met with in young people.

Relative, when it is possible to accommodate for

a near point by converging to a point still nearer, in fact, by squinting.

Facultative, when objects can be clearly seen with or without convex glasses.

In youth the hypermetropia may be facultative, becoming in middle age relative, and in old age absolute.

Causes of Hypermetropia:

1. The antero-posterior diameter of the eyeball is too short (axial hypermetropia). This is by far the most common cause and is congenital.
2. A flattened condition of the cornea, the result of disease or occurring congenitally.
3. Absence of the lens (aphakia).
4. Detachment or protrusion of the retina, owing to a tumour or exudation behind it.
5. A diminution in the index of refraction of the aqueous or lens.

The following are the chief points in which the hypermetropic eye differs from the emmetropic; it is less than the normal in all its dimensions, especially the antero-posterior: the optic nerve is smaller, and contains fewer fibres, while the expansion of the retina is also less. For these last two reasons, when the hypermetropia is high, the acuteness of vision is frequently below the normal. When the development is very imperfect it constitutes the condition known as "microphthalmos."

Hypermetropia, therefore, is usually due to shortening of the axis of the eyeball.

The following table shows the amount of shortening for each dioptre of hypermetropia, the axial line in emmetropia being estimated at 22·824 mm.

For ·5 D. of H.	there is	a diminution in	the axial line of	·16	mm.
1· D.	„	„	„	·31	„
1·5	„	„	„	·47	„
2·	„	„	„	·62	„
2·5	„	„	„	·77	„
3·	„	„	„	·92	„
3·5	„	„	„	1·06	„
4·	„	„	„	1·21	„
4·5	„	„	„	1·35	„
5·	„	„	„	1·5	„
6·	„	„	„	1·76	„
7·	„	„	„	2·03	„
8·	„	„	„	2·28	„
9·	„	„	„	2·53	„
10·	„	„	„	2·78	„

Hypermetropia may be looked upon as a congenital defect, frequently also it is hereditary, several members of the same family suffering from it.

The ciliary muscle, upon the action of which the accommodation depends, is much larger than in emmetropia, the anterior portion, which consists chiefly of circular fibres, being especially developed, no doubt hypertrophied by the constant state of contraction in which it is kept. This contraction is called into action by the instinctive desire for clear images which all eyes possess, the accommodation having to be used for distant, as well as for near objects. Another result of the constant and excessive accommodation, is that the convergent power, with which it is so intimately linked, is kept in a state of constant tension,

so that in many children *convergent strabismus* is gradually produced. To understand how this convergent strabismus becomes developed, I must refer the reader to the chapter on that subject.

As the lens and iris are more forward, the anterior chamber is shallower, the centre of motion is relatively further back, while the angle *a* which is formed between the visual and optic axis is invariably greater, averaging about 7° (see p. 175). The result of this large angle *a* in hypermetropia is, that the eyes often have an appearance of divergence, so that it has been mistaken for real divergence, whereas in myopia, the small angle causes the eyes to look as if they converged.

The external appearance of the hypermetropic eye is often characteristic. The sclerotic looks flat in front, and makes a strong curve backwards in the region of the equator; this can be well seen on extreme convergence; the anterior chamber is shallow, the pupil small, and there is apparent divergent strabismus.

Sometimes the face also has a characteristic appearance, being flat looking, with depressed nose, shallow orbits, and the eyes set far apart. Frequently, however, there is no distinctive physiognomy.

Hypermetropia is by far the most frequent condition of the refraction and is very liable to asymmetry, as will be shown when speaking of astigmatism.

Symptoms of Hypermetropia.—The patient sees well at a distance, but has difficulty in maintaining clear vision for near objects: and since the hypermetropia, can be

more or less corrected by accommodation, if the er be of a low degree (as 2 or 3 D.), no ill-effects may f some time be noticed; at length, however, a point reached, when the accommodation is not equal reading and near work, and accommodative asthenop is the result (p. 191). This is especially liable to sho itself after an illness, or if the patient's health ha deteriorated from over-work, anxiety, or other cause. He then complains that after working or reading fo some time, especially during the evenings, the typ becomes indistinct, and the letters run together: afte resting awhile the work can be resumed, to be agai shortly laid aside from a repetition of the dimness: the eyes ache, feel weak, water, &c., frequently headache supervenes; there is a feeling of weight about the eyelids and a difficulty of opening them in the morning. When the hypermetropia is of high degree, the patient may be said by his friends to be shortsighted, because when reading, he holds the book close to his eyes; by doing this he increases the size of his visual angle, and thus gets larger retinal images; this is counter-balanced by increase in the circles of diffusion, but as the pupils also contract by approaching the book to his eyes, some of these are cut off; so that the advantage is in favour of holding the book close, especially as the patient is probably not accustomed to clear well-defined images. In some cases the ciliary muscle contracts in excess of the hypermetropia, so that parallel rays focus in front of the retina, and the patient therefore presents many of the symptoms of myopia: we should always be on our guard against such cases. The manner in which

the patient reads the distant type is often a guide to us in hypermetropia, he takes a considerable time to make out each line, and yet if not hurried, eventually reads the whole correctly. On looking at the eyes one notices that they are red and weak, the lids look irritable, and on eversion the conjunctiva is hyperæmic, especially that of the lower lids, the papillæ being frequently enlarged, and the edges of the lids sometimes affected with sycosis. All these symptoms are probably the commencement of troubles, which, if allowed to go on, may develop into granular lids, derangements of the lachrymal apparatus, &c., this much we can see; how much more injurious must be the changes which are liable to take place in the interior of the eyeball from prolonged hyperæmia! It cannot be too forcibly insisted on, that in all ophthalmic cases, except those of an acute character, the refraction should be taken and recorded as a matter of routine, since complaints which prove very intractable, are often easily and quickly cured when the proper glasses have been prescribed.

As the patient advances in age he becomes prematurely presbyopic, so that at thirty-five he may suffer from the same discomforts as an emmetrope of fifty.

To test the hypermetropia and measure the amount, we take the patient's visual acuteness, each eye separately, and having found that they are alike in their refraction, we try the two together; stronger glasses being often borne when both eyes are used, than when one is excluded from vision.

The *strongest* convex glass with which he is able to read $\frac{6}{6}$, or with which he gets the greatest acuteness of vision, is the measure of the *manifest* hypermetropia (Hm.). This is not, however, the total hypermetropia, for if the accommodation be paralysed, by applying a solution of atropiæ sulp., gr. iv to ℥j, three times a day for four days (when we may feel sure that not the least vestige of accommodation remains), a much stronger glass can be tolerated, and will be required to enable the patient to read $\frac{6}{6}$. This strong glass represents the total hypermetropia, the additional amount to that found as Hm. being called *latent* (Hl.).

The following plan, which I learnt from Mr. Tweedy, is an excellent one for measuring the manifest hypermetropia. Place in spectacle-frames before the eyes such convex glasses as over correct the Hm. (+4 D. will usually do this); then hold in front of these, weak concave glasses, until we find the *weakest*, which thus held in front of +4 D. enables $\frac{6}{6}$ to be read; the difference between the glasses is then the measure of the Hm. By this plan the ciliary muscle is encouraged to relax, and we get out a larger amount of manifest hypermetropia. Thus supposing −2 D. the weakest glass which held in front of the convex 4 D., enables the patient to read $\frac{6}{6}$, +2 D. is the measure of the Hm. (+4 D.−2 D.= +2 D.). As age advances the accommodation diminishes, and the latent hypermetropia becomes gradually manifest. Thus, a person may have 6 D. of hypermetropia latent at 10 years of age, 3 of which may have become manifest at 35, and

the whole of it at about 65 or 70, when the total hypermetropia is represented by the manifest.

With the advance of age certain changes take place in the structure of the crystalline lens, by which its refraction becomes diminished; this change takes place in all eyes, and at a regular rate; thus at fifty-five the refraction has diminished ·25 D., at sixty-five ·75 D., at sixty-eight 1· D., and at eighty as much as 2·5 D. Hypermetropia when thus occurring in eyes previously emmetropic is styled *acquired hypermetropia,* in contradistinction to the congenital form, which is called *original hypermetropia.*

Cohn and Erismann are of opinion that the normal refraction of the eye in early childhood is hypermetropic; some remain so, a considerable number become emmetropic as they get older, and a certain percentage of these pass on to myopia.

The **treatment of hypermetropia** consists obviously, in prescribing such convex glasses as will give to rays passing through them an amount of convergence, so that they will meet on the retina without undue accommodation. It might be thought that having obtained the measure of the *total* hypermetropia, nothing remained but to give such positive glasses as exactly neutralize the defect, and that we should then have placed the eye in the condition of an emmetropic one. Such at first was thought to be the case, though it is by no means so, because persons who have been accustomed to use their accommodation so constantly, both for near and distant objects, as is the case with hypermetropes, have very large ciliary muscles which they

cannot suddenly completely relax; possibly also the elasticity of the lens capsule is somewhat impaired.

In children and patients under twenty years of age, it is much better to atropize them at the first, and so measure once and for all, the amount of total hypermetropia; otherwise it will frequently be found, that the spectacles have to be constantly changed, the asthenopia is unrelieved, and probably the patient has to be atropized after all, or becomes dissatisfied and goes off to some one else. Another reason in favour of atropine is, that with it we cannot possibly mistake cases of spasm of the ciliary muscle in hypermetropia for myopia, which might otherwise happen, since the spasm causes the lens to become so convex that parallel rays are even made to focus in front of the retina, thus simulating myopia.

It must always be borne in mind, that it is dangerous to atropize patients above the age of thirty-five, many well-marked cases of "glaucoma" having been traced to the use of this drug; moreover, as age advances the latent hypermetropia gradually becomes manifest, so that the necessity for paralysing the accommodation becomes less.

There exists some difference of opinion among ophthalmic surgeons, as to the amount of the total hypermetropia we ought to correct; some give such glasses as neutralize the *manifest* hypermetropia only, while others, after estimating the total, deduct perhaps 1 D. from this. It will be found that patients vary much as to the amount of correction which is most comfortable for them.

Donders has given the following practical rule—that we should prescribe such glasses for reading as correct the *manifest* and one fourth of the *latent* hypermetropia, and this will be found to work well.

For example, a child having 6 D. of hypermetropia of which 2 only are manifest, will require +3 D. for reading. At the age of twenty, about 4 D. will have become manifest, and the patient will then want +4·5 D., at forty, 5 D. will be manifest, and he may then be able to bear full correction.

Hence it will be seen that, as age advances, the spectacles will have occasionally to be changed for stronger ones, as the latent hypermetropia gradually becomes manifest.

The question arises, should spectacles be worn constantly or only for near work? So long as distant objects ($\frac{6}{6}$) can be seen comfortably without them, their use is unnecessary except for reading and near work. This is generally the case in young persons where the hypermetropia does not exceed 3 or 4 D. When a convex glass improves distant vision, then such can be constantly worn; somewhat stronger ones may be required for reading, &c., this is frequently the case with old people.

The disadvantage of using spectacles constantly is, that after wearing them for some time, the patient finds he is unable to see without them, which is a serious inconvenience, so that the plan is, not to give spectacles for constant use, until the hypermetropia has become relative or absolute.

In cases of concomitant squint, spectacles which

correct the hypermetropia are to be worn constantly, and here our object must be to give as near the full correction as is consistent with the patient's comfort, this we can only find out by experiment in each case; the best plan is to measure under atropine the total hypermetropia, deduct 1 D. for the tone of the ciliary muscle, and give this correction for constant use.

In the diagnosis and estimation of hypermetropia several methods are useful. We first estimate the *acuteness of vision*, remembering that being able to read $\frac{6}{6}$ does not exclude hypermetropia, and that we must in all cases try convex glasses, and if the same letters can be seen with, as without them, then the patient certainly has hypermetropia, and the *strongest* convex glass with which he sees them is the measure of his Hm.; we next proceed to *retinoscopy*, with this method we get a reverse shadow, the quicker the movement and the brighter its edge, the lower is the degree of hypermetropia (see page 79).

With the ophthalmoscope by the *indirect method* of examination, the image of the disc is larger than in emmetropia and diminishes on withdrawing the objective from the eye (p. 56).

By the *direct* examination at a distance, an erect image of the disc is seen, which moves in the same direction as the observer's head (page 60). On approaching the eye, the accommodation of the observer and observed being relaxed, a convex glass is necessary behind the ophthalmoscope, to enable the observer to bring the diverging rays from the observed, to a focus on his retina; the strongest *convex* glass with which

it is possible to see the details of the fundus clearly, is the measure of the total hypermetropia, Fig. 43.

Asthenopia and convergent strabismus, two of the most frequent results of hypermetropia, will be treated of in Chapters IX and X.

See Cases 1 and 2, page 97; also 10, 12, and 17, page 203.

APHAKIA

APHAKIA ('A priv, φακός lens) is the name given by Donders to that condition of the eye in which the lens is absent. There are several causes, by far the most frequent being one of the various operations for cataract, extractions, needle operations, &c. Besides these, aphakia may be caused by dislocation of the lens from injury, or may occur spontaneously, the latter being probably the cause of congenital cases where no lens can be seen.

Aphakia necessarily converts the eye into a very hypermetropic one. The length of the eyeball which would be required (the curvature of the cornea being normal and the lens absent) to bring parallel rays to a focus on the retina is 30 mm., whereas normally the antero-posterior diameter of the eyeball is only about 23 mm.

To **test** aphakia; when a bright flame is held in front of and a little to one side of a normal eye, three images of the flame are formed, one erect on the cornea, another erect on the anterior surface of the lens, and a third inverted, and formed on the posterior surface of the

lens. On moving the flame up or down, the erect images move with it, and the inverted one in the opposite direction. In aphakia two of these images are absent, viz. those formed on the two surfaces of the lens.

Treatment.—Strong convex glasses will be required to take the place of the absent lens, the previous refraction of the eye of course influencing their strength. If hypermetropic, stronger glasses will be required; if myopic, weaker.

The glass usually required by an eye previously emmetropic, to bring parallel rays to a focus on the retina, is from 10 to 13 D.

As every trace of accommodation is lost with the lens, stronger glasses will be required for reading or near work, and to find out the necessary glass for a certain distance, we have only to add to the distance glass, one, whose focal length equals the distance at which we wish our patient to see. Thus if he require + 10 D. for distance, and wish to see to read at 25 cm., we add + 4 D. to his other glass and the resulting + 14 D. will bring up his vision to 25 cm.

The patient may be taught a sort of artificial accommodation by moving his spectacles along his nose, nearer or farther from the eyes, his working point being thereby moved away or brought nearer to him.

In correcting aphakia it will often be found that the vision is below the normal. Frequently also there is some astigmatism, especially in cases after cataract extraction.

See Case 23, page 216.

CHAPTER VI

MYOPIA (M).

Myopia (Μύω, I close; ὤψ, the eye) or short sight, in the opposite condition to hypermetropia.

It has already been shown that in emmetropia, the eye is of such a length, that parallel rays after passing through its refracting system, focus exactly on the retina; in hypermetropia the eyeball is too short so that parallel rays focus behind the retina, but in myopia the eye is too long for its refracting system and parallel rays focus in front of the retina.

Donders proposed the name of brachymetropia, but we have been so long accustomed to the old term myopia, that it seems better not to change it.

Parallel rays, therefore, falling on a myopic eye, focus in front of the retina, cross and form circles of diffusion (Fig. 62) in place of a clear image.

Divergent rays only, focus on the retina and hence it is necessary, that the object looked at be brought so near, that rays coming from it are sufficiently divergent (Fig. 63), or they must be rendered so by passing through a concave lens (Fig. 64).

We may say then, that in myopia the retina is at

Fig. 62.

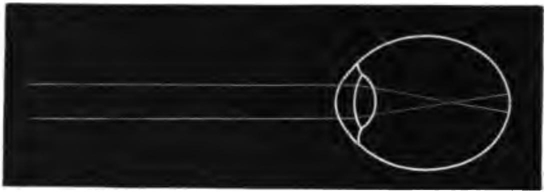


Fig. 63.

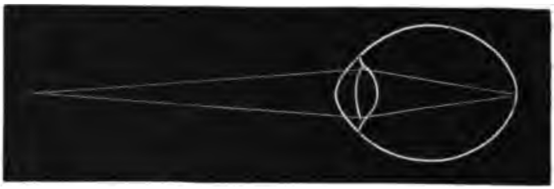
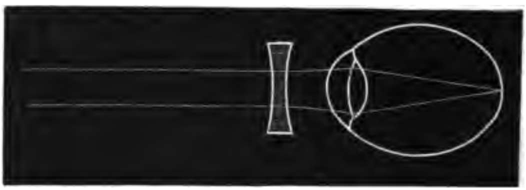


Fig. 64.



the conjugate focus of an object, situated at a finite distance. The accommodation being at rest, an object situated at this point will be distinctly seen, further off it will be indistinct, nearer, it can still be seen clearly by putting in force the accommodation.

The greatest distance at which objects can be seen clearly, is called the far point (punctum remotum) and

is always at a definite distance. The higher the myopia the nearer to the eye is its punctum remotum (p. r.).

The nearest point of distinct vision is the punctum proximum (p. p.) and is determined by the amount of the accommodation. To find out the punctum proximum, we place in the patient's hand the near type and note the shortest distance for each eye separately, at which the smallest type can be read, or we measure it by the wire optometer in the manner before described. The range of accommodation is often equal to that in emmetropia, but in the higher degrees of myopia it becomes considerably diminished.

The greatest distance at which an object can be clearly seen, is the exact measure of the myopia, for instance, if the far point be at one metre, a concave glass of that strength (— 1 D.) would render parallel rays as divergent, as if they came from a distance of one metre, and with a glass of this focus, the person would be able to see distant objects clearly.

Myopia was for a long time thought to be due to an increase in the convexity of the cornea, but as a matter of fact the cornea is usually less convex, and as a rule, the greater the myopia, the less the convexity.

It has also been attributed to an increase of the index of refraction of the lens, and such may occasionally be the case in the development of cataract.

Conical cornea at its commencement often simulates myopia.

It may therefore be stated that myopia almost in-

variably depends upon a lengthening of the visual axis (axial myopia) accompanied in many cases by the formation of a *posterior staphyloma,* which further increases the antero-posterior diameter of the eyeball. This bulging when it occurs, takes place at the outer side of the optic nerve towards the macula, and consists of an extension and thinning of the sclerotic and choroid backwards, with more or less atrophy of the latter.

So constant is this lengthening of the visual axis in myopia, that from the number of dioptres of myopia can be calculated the increase in the length of the eyeball.

The following table from Wecker and Landolt gives the calculation up to 10 D.:

Degree of myopia.		Distance of the p. r. in millimetres.		Increase of length of the myopic eye in millimetres.
·5 D.	...	2000	...	·16
1·	...	1000	...	·32
1·5	...	666·6	...	·49
2·	...	500	...	·66
2·5	...	400	...	·83
3·	...	333·3	...	1·
3·5	...	285·7	...	1·19
4·	...	250	...	1·37
4·5	...	222·2	...	1·55
5·	...	200	...	1·74
6·	...	166·6	...	2·13
7·	...	142·8	...	2·52
8·	...	125·	...	2·93
9·	...	111·1	...	3·35
10·	...	100·	...	3·80

Fig. 65 shows a section of a myopic eye from a case at Moorfields, in which the outside measurements

were :—Antero-posterior diameter 30½ mm.; vertical diameter 25 mm.; transverse diameter 25 mm.*

It will be remembered that the emmetropic eye measures in the antero-posterior diameter 23 mm.

FIG. 65.

In Fig. 66 the amount of accommodation is indicated in a myope of 2 D, by the number of spaces through which the thick lines pass; thus at the age of thirty

FIG. 66.
Dioptres.

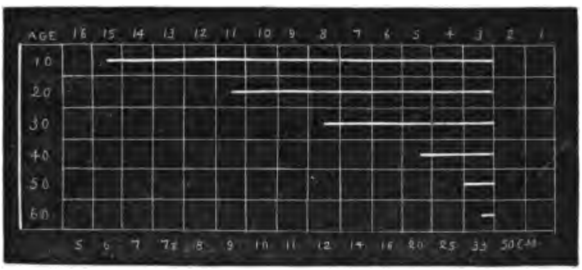


Diagram showing the amount of accommodation at different ages in a case of myopia of 2 D.

* For the particulars of this case I am indebted to Mr Jennings Milles.

the accommodation is equal to 6 D., and the near point will be 12 cm. the distance of the punctum proximum is given for each dioptre at the bottom of the diagram.

As the punctum remotum in myopia is situated at a finite distance, therefore for the same amplitude of accommodation, the punctum proximum is nearer the eye in myopia than in emmetropia. The near point gradually recedes with advancing age at the same rate whatever the refractive condition of the eye; it is clear, then, that the near point in myopia will be longer in reaching that point (22 cm.) at which presbyopia is arbitrarily stated to commence than in emmetropia, so that in prescribing glasses for presbyopia, the amount of myopia has to be deducted from the glass, which the emmetrope would require at any given age.

If the myopia amount to 4·5 D:, then the patient can never become presbyopic, because his punctum remotum is only 22 cm. away, so that he will always be able to see at that distance. Most people imagine, that those who do not require glasses with advancing age, have very strong eyes; how frequently does one hear the remark, when inquiring of a patient's family history, "Oh! my father had excellent sight, he was able to read at sixty without glasses." This is proof positive that he had myopia, though probably you will be unable to convince the patient of this fact.

In hypermetropia it was shown, that the power of accommodation had to be used in excess of the convergence. In myopia we have the opposite defect, the patient having to converge in excess of his accom-

modation; thus, if he be myopic 4 D. his far point will be at 25 cm., when looking at an object at this distance, it is necessary for him to converge to this particular point, his angle of convergence being 4, while his accommodation remains passive.

Donders divides myopia into three classes:

1st. The *stationary,* where it does not exceed 2 D. at ten years old, nor 2·5 D. at forty.

2nd. The *temporarily progressive,* which may progress from 4 to 8 dioptres between the ages of ten and thirty. If the general health be good it seldom increases much after the age of twenty-six.

3rd. The *progressive,* which increases steadily and constantly from an early age.

Causes.—The two chief factors in the production of myopia, are, a congenital difficulty in bringing the optic axes into convergence, and in the application of the individual himself to work of a very fine character. In a large majority of cases, myopia is acquired, but in a small proportion of cases it may be congenital; this latter form frequently attains a high degree in early life, may occur in one or both eyes, and bears no relation to the occupation of the patient. Though seldom congenital it not unfrequently happens that one or other of the parents has suffered from myopia. There is little doubt that in many cases there is an hereditary tendency to it, which, transmitted through several generations, under favorable circumstances for its development, becomes very decided.

As in the greater number of cases of myopia the factor which tends to produce it, is the prolonged use

of the eyes on near objects especially while young; we may set down myopia as one of the results of civilisation and education, and in these days of high pressure and competitive examination, it is constantly on the increase. The result of the very numerous statistics that have been collected, especially by German ophthalmologists (myopia in Germany is exceedingly common), points to the production of myopia in direct proportion to the amount of education. The amount of myopia was found to be much greater in town than in country schools, no doubt because the general health was better amongst those living in the country. Erismann has come to the pleasant conclusion, that if myopia increase in the same ratio as it has done during the last fifty years, in a few generations the whole population will have become "myopic." It behoves us therefore to endeavour by good general advice and hygiene, to do all in our power to control the onward march of this disease. Those who are interested in the construction of schools, where the object is to educate the young, and at the same time to reduce, as far as possible, the causes which are liable to produce or increase myopia, should refer to a lecture on this subject by my colleague, Mr Power, in the 'Lancet' of September 22nd, 1883.

Myopia is almost unknown among the savage races.

Donders says that hypermetropia never gives way to myopia, but Cohn and Erismann are of opinion, that the normal refraction of the eye in childhood is hypermetropic, that some few remain so, a great

number becoming emmetropic as they get older, and that a large percentage of these pass on to myopia.

In proof of this hereditary tendency to myopia, Dr Cohn has summarised the statistics of various German writers on this subject. Thus in public schools myopia was found to exist without predisposition in 8 per cent., with predisposition in 19 per cent. In the higher schools the result was: without predisposition 17 per cent., with predisposition 26 per cent.

Residence in towns is also conducive to short sight, by causing people to gaze constantly at near objects.

The cause why myopia when once established is very liable to increase, is that the extreme convergence, which is necessary to enable the patient to see at the limited distance, to which he is confined, causes the weakest part of the globe (that part in fact which is least supported) to bulge, forming a posterior staphyloma. In support of this method of production of myopia, may be stated the well-known fact, that people, such as watchmakers and jewellers, who habitually use a strong convex lens before one eye, and work at the focal distance of that lens, are not especially liable to myopia, proving that close work without convergence does not tend to produce it. As the eyeball becomes elongated its movements become more difficult, and the pressure produced by the muscles during prolonged convergence, tends still further to increase the myopia.

The stooping position which so many myopes take up, causes an accumulation of blood in the eyeball, which tends to raise the tension as well as materially

to interfere with its nutrition. Hence results a state of congestion, softening, and extension, leading to a further increase of the myopia. The more advanced these changes, the more difficult is it for the myopia to become stationary.

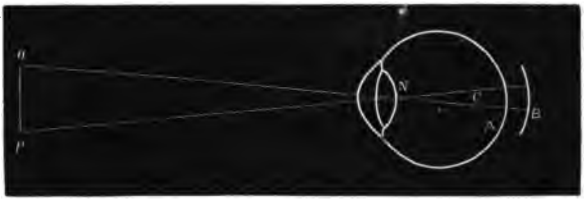
In addition to these two causes, extreme convergence and the stooping position, it is possible that, as a result of the constant convergence, the optic nerves may be somewhat pulled upon, and thus further assist in producing myopia.

Cases of nebulæ, cataract, and other causes of imperfect sight in children, may give rise to myopia by causing them to hold objects they wish to see close to the eyes.

Symptoms.—The patient sees distant objects badly and near objects well. The eyes look prominent; the pupils are usually large in young people, as age advances they contract, thus diminishing the circles of diffusion, and so slightly improving vision. Eserine acts in the same manner, so does the nipping together of the eyelids, which is so characteristic of patients suffering from myopia, and to which the disease owes its name. The acuteness of vision is frequently below the normal, though objects within the patient's far point appear larger than they do to the emmetrope; the distance between the nodal point and the retina being greater in myopia (Fig. 67). This, however, may be partly counterbalanced by the stretching of the retina, so that, although the image may be somewhat larger, it may not cover a greater number of cones than would be the case in an emmetropic eye.

If the myopia be progressive, frequent limitations in the field of vision occur, in the form of scotomata due to patches of retinal atrophy; in addition to seeing distant objects badly, the patient complains of pain, fatigue, and intolerance of light, with a state of irri-

FIG. 67.



A. The retina in an emmetropic eye. B. The retina in a myopic one. C. The visual angle. N. The nodal point. The distance from NB is greater than NA, and the image of OP is greater at B than at A.

tation, especially after using the eyes by artificial light. There may be hyperæmia of the eyes and lids, spasm of the accommodation (which increases the apparent amount of myopia), pain in the eyeballs on pressure, photopsia, an appearance of convergence due to the small size of the angle *a* (p. 176), together with "muscæ volitantes." These last are often a source of great anxiety; the patient may, however, be assured, that although they cannot be removed, there is no cause for uneasiness: these muscæ are probably the remains of vitreous cells which, being situated a considerable distance in front of the retina, throw shadows on it, and are projected outwards as much larger images than would be the case in an emmetropic eye: they appear to the patient as black spots.

The ciliary muscle is smaller than in emmetropia, the circular fibres (which are so hypertrophied in hypermetropia) being almost absent.

The internal recti muscles often act badly, so that convergence becomes painful and difficult, often going on to strabismus divergens.

When the myopia is of high degree, the patient often uses one eye only for reading, then of course he does not require to converge.

The popular impression that myopia decreases with advancing age is incorrect; the far point can at best remain stationary, while the near point gradually recedes, and if a person of fifty, reads at a further distance than he did at twenty, the reason is that at the latter age he did not read at his far point. A young myope with fair accommodation may find it difficult to keep this function passive, while converging to the necessary distance for reading; the pupils become smaller with age, thus cutting off some of the patient's circles of diffusion and enabling him to see objects somewhat more clearly. According to Donders, the refraction of the eye does somewhat diminish as age advances, in this case the myope's vision would improve (see p. 113).

Ophthalmoscopic Appearances.—With the ophthalmoscope, a crescentic-shaped patch of atrophy is frequently seen on the outer side of the optic disc, embracing it by its concave edge; this is called the "myopic crescent."

In an early stage the crescent looks somewhat white showing the large choroidal vessels often more

distinctly than on the adjoining parts, gradually, the blood-vessels disappear, leaving the white sclerotic, which shows up plainly against the red of the fundus. Some remains of pigment about the convex border of the crescent are often seen, and frequently there is some thinning of the choroid beyond. The retina seems to participate in this atrophy much less than might have been expected.

Although the atrophy usually assumes the crescentic form, as shown in Fig. I of the plate which was drawn from the fundus of a young man, aged twenty, with a myopia of 4 D., yet it may vary much, sometimes forming a complete ring round the optic disc (II), or it may extend outwards (III), the broadest part being usually between the disc and the macula; sometimes there is excavation of the atrophic part.

The optic nerve is occasionally displaced, somewhat inwards, and the disc, instead of being directed forwards, looks forwards and outwards, making it appear oblong in shape from its being seen obliquely (III); the retinal vessels that pass over the atrophied part are often straight in their course, and show up very clearly against the white sclerotic.

The formation of the crescent is much influenced by the amount of myopia. In slight degrees in young people it is often absent, but in cases of 6 D. or more, at the age of twenty, we invariably find a well-marked crescent.

Secondary choroidal changes are also apt to take place in the yellow spot, as shown in Fig. IV, which is copied from the 'Atlas' of Wecker and Jaeger; when

these changes take place they cause great impairment of vision, due either to extension of the atrophy outwards, or to disease commencing there independently. If the disease be progressive, the vitreous becomes disorganised, opacities forming in it; the lens may become cataractous, especially at the posterior pole, hæmorrhages may occur, and detachment of the retina sometimes takes place.

Further it may be said that myopes are especially liable to accidents.

The **diagnosis and estimation** of myopia is easy. At the distant type the patient requires a concave glass to enable him to read $\frac{6}{6}$. The *weakest* lens with which he is able to read it is the measure of his myopia; always remember the patient is apt to choose too strong a glass if left to himself; to prevent this and enable us to make an exact record of the condition of the refraction, by which we may judge if the myopia is stationary or progressive, it is much the best plan in young people to atropize them in the manner previously described. On placing the near type in his hand, he will be found to be able to read the smallest print, though at a *shorter* distance than that for which it is marked. The extreme distance at which he is thus able to read it, is his far point, the measure of which is also a measure of his myopia: this is a most useful guide to us; for instance, he reads No. 1 at 25 cm. but no farther; ($\frac{100}{25} = 4$ D.), therefore 4 D. is the measure of the myopia, and such a glass will render parallel rays so divergent, that they will seem to come from 25 cm. Had he been able to

read it at 10 cm. only, then ($\frac{100}{10}$ = 10 D.) − 10 D. will be the measure of the myopia.

With **retinoscopy** the shadows move in the same direction as the mirror, so long as the observer is beyond the patient's far point (Chap. IV).

With the ophthalmoscope, by the **indirect** examination, the disc looks smaller than in emmetropia, and becomes larger on withdrawing the objective farther from the eye (Figs. 37 and 38).

By the **direct** method of examination at a distance, with the mirror alone, an inverted magnified image of the disc can be clearly seen, provided always that the observer be not nearer the aërial image than his own near point (Fig. 41). The lower the myopia the greater the image, because the longer is the distance between the image and the myopic eye. On moving the head from side to side, the image will always move in the opposite direction, showing that it is an inverted one. When we bring the ophthalmoscope close to the eye, the fundus cannot be clearly seen until a concave glass is placed in front of the observing eye. The *weakest* concave glass with which the details of the macula and disc can be clearly seen (the observer's eye being emmetropic and the accommodation relaxed) is a measure of the myopia (Fig. 44). This test may be relied upon for the lower, but not for the higher degrees of myopia.

The **treatment** of myopia.—The chief indications are:

1st. To prevent the increase of the myopia.

2nd. To enable the patient to see well.

3rd. To prevent the various troubles from which myopes are so liable to suffer, as asthenopia, divergent strabismus, &c.

To carry out the first of these indications, strong convergence and the stooping position, both of which play so important a part in the production of myopia, must be avoided, the patient being directed never to read in a train or carriage, where every movement requires a change in the accommodation, nor to look at near objects for too long together: the natural tendency for a myope who is excluded in great measure from seeing distant objects, is to devote himself to near ones. In reading, writing, or working, he must keep 35 cm. away from the book or paper, use books printed in good, bold type, and not write too small, while the desk and seat should be conveniently arranged so as to avoid stooping. He should do as little as possible by artificial light; when necessary, it is best to use a reading lamp, so placed that it throws the light down upon the work, leaving the remainder of the room in comparative darkness, so that when the eyes become tired they may be rested by turning them from the light. The stooping position must be strictly avoided, as it causes an increased flow of blood to the interior of the eyeball, and at the same time by compressing the veins in the neck, obstructs the returning blood and so produces hyperæmia with symptoms of irritation, and possibly some slight increase of tension. When reading or writing, he should sit with his back to the window, so that the light may fall on his book or paper over his left

shoulder, the shadow of his pen being thus thrown to the right, enabling him to see plainly the letters he is forming.

Attention must be paid to the general health; iron internally often being especially useful, combined with regular outdoor exercise. When symptoms of irritation show themselves, with a rapid increase in the myopia, complete rest must be given to the eyes, and in no way can this be so conveniently carried out, as by dropping into the eyes a solution of atropine (gr. j to ℥j) three times a day, for some two or three weeks; counter-irritation may be applied to the temples and behind the ears in the shape of small blisters, or by a solution of iodine. Sometimes where there are symptoms of congestion present, the artificial leech applied to the temple once a week for a few weeks does much good. As the irritation gradually subsides, the patient may be allowed to do a little reading daily, in a good light, the eyes all the time being kept under atropine; he may require glasses to enable him to do this. Thus, if he have myopia of 3 D. he will not require them, his far point being at 33 cm.; if he has $-$ 1·5 D. he would require $+$ 1·5 D. to enable him to read at about 35 cm. ($+$ 3 D. $-$ 1·5 D. $=$ $+$ 1·5 D.); if the myopia is 6 D. he will require $-$ 3 D. to put back his far point from 16 to 35 cm. ($+$ 3 D. $-$ 6 D. $=$ $-$ 3 D.).

So long as the myopia is progressing it must always be a source of anxiety to us.

To enable the patient to see well both near and distant objects, as well as to prevent extreme convergence, we must correct the myopia. In young people

3rd. To prevent the various t
myopes are so liable to suffer, as a
strabismus, &c.

To carry out the first of the
convergence and the stooping p
play so important a part in the
must be avoided, the patient
read in a train or carriage,
requires a change in the acc
at near objects for too lon
tendency for a myope who i
sure from seeing distant ob
to near ones. In reading
nust keep 35 cm. away fr
oks printed in good, b
all, while the desk an
anged so as to avoid
le as possible by ar
is best to use a re
ows the light do
main der of the ro
t wh er the

hes to read or work. Thus
distant vision, the patient
which to read at 33 cm. (— 9
) — 6 D. would be the glass
able the patient to read at 33
accommodation.

be required for music. When
degree and we are certain that
nary, folders may be allowed for
ing used for near work.

occasionally allowed in low degrees
ing at distant objects; they have
hat as one eye only is used, the sight
deteriorate.

ar asthenopia is present, prisms with
ards, which diminish the necessity for
ith or without concave glasses, are of

ophobia is a prominent symptom tinted
y be comfortable.

rtant to impress on the patient that the
eading, are not given to enable him to see
o *increase the distance* at which near objects
n.

where the myopia has been estimated under
it is necessary to add on to the glass so
·5 D. for the tone of the ciliary muscle, as it
t the full correction under atr
ch weaker, than the correctio

nd 19, pages 205 and 214.

CHAPTER VII

ASTIGMATISM AND ANISOMETROPIA

Astigmatism, 'A priv, στίγμα a point.

Hitherto we have seen, that the cornea usually takes but little part in the defects we have been considering. It has been shown that hypermetropia is almost invariably due to the eyeball being too short, and myopia to its being too long. We now come to a defect in which the curvature of the cornea plays a very important part, with or without some decrease or increase (from the emmetropic standard) in the antero-posterior diameter of the eyeball; I refer, of course, to astigmatism, which is the commonest of all the refractive errors, few cases of hypermetropia being entirely free from it, and still fewer cases of myopia. Astigmatism, then, may be defined as that state in which the refraction of the several meridians of the same eye is different; for instance, the horizontal meridian may be emmetropic, the vertical hypermetropic.

It is usually congenital, but may be acquired, and frequently there is some hereditary tendency.

Astigmatism may be divided into two chief divisions:

1. Irregular.
2. Regular.

The irregular variety, which consists in a difference of refraction in the different parts of the same meridian may be further subdivided into normal and abnormal:—(*a*) The normal irregular astigmatism is due in great measure to irregularities in the refracting power of the different sectors of the lens; it causes a luminous point to appear stellate, as is the case when looking at a star, which is in reality round. (*b*) The abnormal variety may arise from the condition of the lens or of the cornea; when the lens is in fault, it may be a congenital defect, it may be due to changes taking place in the lens itself, or to partial displacement by accident. The changes in the cornea which may produce it, are conical cornea, nebulæ, and ulcers. Little can be done in the way of glasses towards correcting this form of astigmatism, though much improvement of vision sometimes occurs, when stenopaic spectacles are worn, the opening being made to suit the peculiarity of each case.

We now pass on to the much more common form, which can frequently be exactly corrected by the help of plano-cylindrical lenses.

Regular Astigmatism is due to the curvature of the cornea being different in the two meridians, that of maximum and minimum refraction; these are called the chief meridians, and are always at right angles to each other.

In the normal eye the cornea is the segment of an ellipsoid and not of a sphere, so that there is a slight difference in the refraction of the two chief meridians, the focus of the vertical meridian being slightly shorter than that of the horizontal.

This can easily be proved by looking at a card on which is drawn two lines crossing each other at right angles, the card is held close to the eye and gradually made to recede; both lines cannot be seen at the same time with equal clearness, the horizontal being seen clearly at a shorter distance than the vertical line. So long, however, as the acuteness of vision is not impaired, it goes by the name of normal astigmatism or regular astigmatism of the normal eye.

Parallel rays passing through a convex spherical glass come to a focus at a point. If the cone of light thus formed be divided perpendicular to its axis, at any point between the lens and its focus, or beyond the focus after the rays have crossed and are diverging, a circle is formed. In astigmatism the case is different; if parallel rays pass through a convex lens, which is more curved in the vertical than in the horizontal meridian, those which pass through the vertical meridian come to a focus sooner than those which pass through the horizontal; and the resulting cone instead of being circular, as in the previous case, will be more or less of an oval, forming a circle only at one point (4, Figs. 68 and 69). Let us now divide this cone at different points at right angles to its axis, and notice the shape of the diffusion patches thus produced.

At 1 an oblate oval is formed, at 2 a horizontal

FIG. 68.

FIG. 69.

Section of cone of light at 1, 2, 3, 4, 5, 6, 7, Fig. 68.

straight line, the vertical rays having come to a focus; at 3, 4, 5, the vertical rays have crossed and are diverging, and the horizontal rays are approaching; at 4 a circle is formed; at 6 a vertical straight line, the horizontal rays have met and the vertical are still diverging; a large prolate ellipse is formed at 7.

The space between the two points at which the vertical rays V V, focus at V, and the horizontal rays H H, focus at H, is called the interval of Sturm (I, Fig. 70).

FIG. 70.

Regular astigmatism was at one time thought to be due to defects in the curvature of the lens, but it has since been proved to depend almost entirely on asymmetry of the cornea. The lens may, however, influence it in two ways:—1st. Its two chief meridians may not correspond to those of the cornea; 2nd, Owing to the position of the eye the lens may be situated obliquely.

It has been experimentally proved, that slight amounts of corneal astigmatism may be corrected or disguised, by the unequal contraction of the ciliary muscle (one segment of the muscle acting while the rest of the circle remains passive); the curvature of the lens is thus increased, in the direction of the ciliary contraction only.

Astigmatism was first discovered by Thomas Young in 1793, who was himself astigmatic.

In astigmatism the vertical meridian has usually the maximum, and the horizontal meridian the minimum of curvature, corresponding to the astigmatism of the normal eye. To this, however, there are numerous exceptions. Thus, the chief meridians may occupy an intermediate position, or the vertical may have the minimum, and the horizontal the maximum of curvature. Whatever the direction of the two chief meridians, they are always at right angles to each other.

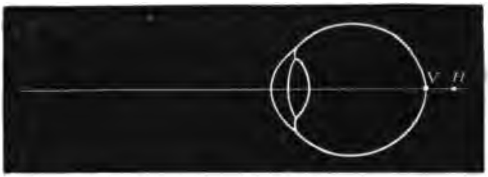
There are five varieties of regular astigmatism:

1. Simple hypermetropic astigmatism.
2. Compound hypermetropic astigmatism.
3. Simple myopic astigmatism.
4. Compound myopic astigmatism.

5. Mixed astigmatism.

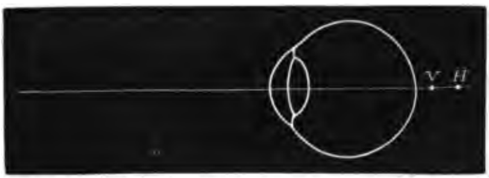
In the first variety, one set of rays (we will assume the vertical, V) have come to a focus on the retina, while those at right angles, the horizontal (H), focus behind the eye. Thus, instead of a point, as in emmetropia, a horizontal straight line is formed on the retina (Fig. 71).

FIG. 71.



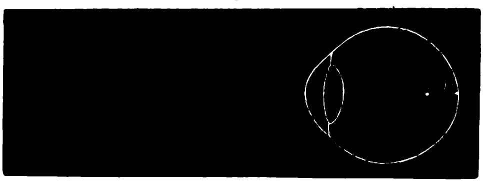
In the second variety, both sets of rays focus behind the retina (Fig. 72)

FIG. 72.



In the third variety, one set of rays (we will assume the vertical) focus in front of the retina, the other set on the retina, thus forming a vertical straight line (Fig. 73).

FIG. 73.



In the fourth variety, both sets of rays focus in front of the retina (Fig. 74).

FIG. 74.

In the fifth variety, one set of rays has its focus in front, and the other set behind the retina (Fig. 75).

FIG. 75.

In the five foregoing figures, the focus of the vertical rays has been placed in front of the focus of the horizontal rays; of course it will be understood that the position of these two foci are frequently reversed.

From what has been said it will easily be seen, that when an astigmatic eye looks at a spot, it sees not a spot, but a *line*, an *oval* or a *circle*, hence its name (a and $\sigma\tau\iota\gamma\mu\alpha$).

It is necessary that it should be thoroughly understood, how the image of a line is formed on the retina: the clear perception of a line depends upon the distinctness of its edge, and to gain a clear image of this line, it is necessary, that the rays coming from a succession

of points which make up this line (they of course also emerge in every direction) should be brought to a focus on the retina, having passed through the cornea at right angles to its axis. Should they not do so, circles of diffusion are formed, which overlap each other and so render the edges ill-defined. The rays which diverge from the line parallel with its axis, overlap each other on the retinal image, increasing its clearness, except at the extremities, where they overlap and cause some slight indistinctness. Thus, a person with simple astigmatism, myopic in the vertical and emmetropic in the horizontal, sees distinctly *vertical* lines, because the rays coming from the edges of the vertical line, pass through the horizontal or emmetropic meridian, while those which come from the line parallel with its axis, pass through the myopic meridian and overlap each other without causing any indistinctness of its edges. Therefore, a patient with simple astigmatism, sees clearly the line which is parallel with his ametropic meridian, and indistinctly the line parallel with his emmetropic meridian.

Symptoms.—There is frequently a want of symmetry about the patient's head or face. If young, and the astigmatism hypermetropic and of low degree, few symptoms may be present; usually, however, the patient complains of defective vision with asthenopia, especially if his work be such, that his accommodation is in constant use; sometimes headache is a very marked symptom, either frontal or occipital; he has probably tried all sorts of spectacles and can find none to suit him. On trying him at the distant type, his

acuteness of vision is always below the normal, the mixed variety of astigmatism affecting it most, and next the compound. We sometimes notice when trying the acuteness of vision, that the patient sees much better if allowed to hold his head on one side; by doing this, he places his nose somewhat in the line of vision of the eye he is using, and so cuts off some of the rays which would otherwise enter his pupil; he thus diminishes his circles of diffusion. It is possible also that if his chief meridians are oblique, by thus tilting them, he brings them to correspond with the meridians of the object looked at. Whether this explanation be the correct one, I know not, but we may generally feel pretty confident, when we see the patient looking at the test type with his head on one side, that astigmatism is present. One frequently hears it said, that images formed on the retina in astigmatism are distorted; this, however, is not the case, as can readily be proved by making one's own eye astigmatic, by placing in front of it a cylindrical glass; a certain amount of blurring and indistinctness is produced, but no actual distortion, the distance between the cornea and retina being insufficient.

Usually both eyes are affected, sometimes quite symmetrically. Frequently, however, there is a great difference, one being almost emmetropic, the other very astigmatic.

In astigmatism when the chief meridians of one eye, are at right angles to the chief meridians of the other, binocular may be much better than monocular vision; we will illustrate this by a simple example. The right

eye we will assume to be hypermetropic, 2 D. in the vertical meridian, emmetropic in the horizontal; the left emmetropic in the vertical, hypermetropic in the horizontal 2 D. We know that the patient, looking at the fan of radiating lines with the right eye only, will see the vertical lines distinctly, the horizontal only by accommodating; with the left eye the horizontal lines will be clearly seen, the vertical ones indistinctly; with the two eyes all the lines will appear distinct, the image in one eye overlapping that of the other. We seldom find a case in which the correction is so complete as in our example, but we meet with cases where partial correction takes place.

In my experience vision is less impaired when the chief meridians are vertical and horizontal, than when they are oblique.

As hypermetropia is more common than myopia, so also is hypermetropic astigmatism of more frequent occurrence than the myopic variety, though few myopes will be found who are quite free from astigmatism. Mixed astigmatism is the least frequently met with.

If, after trying the patient at the distant type, we are not satisfied with the result, though perhaps we have some improvement with either convex or concave glasses, we may suspect astigmatism and pass on to some of the special tests by which it may be diagnosed and estimated.

If astigmatism exist, our first object must be to find out the direction of the two principal meridians, viz. those of maximum and minimum refraction.

Most of the tests for astigmatism are based upon the facts of the perception of a line. An astigmatic eye, looking at a test object composed of lines radiating from a centre, and numbered for convenience sake like the face of a clock, is unable to see all the lines equally clearly. The line seen most distinctly, indicates the direction of one of the two chief meridians; the other chief meridian being of course at right angles to the one most clearly seen. The fan of radiating lines now very commonly used, as well as the clock face with moveable hand of Mr Brudenell Carter, are all convenient test objects. The striped letters of Dr Pray are convenient for indicating one of the chief meridians.

To **test and measure** the astigmatism, we place our patient at a distance of six metres in front of the clock Fig. 76, covering up one eye with a ground glass disc. Supposing he see plainly the 3 lines from 12 to 6, all the other lines being more or less indistinct, those from 3 to 9 most so, and further, if on placing before the eye a weak positive glass, we find that lines from 12 to 6 are blurred, we know then that the horizontal meridian, that is, the meridian at right angles to the clearly defined line, is emmetropic, as well as being one of the principal meridians. We now direct him to look steadily at the lines from 3 to 9, *i.e.* those at right angles to the lines first seen; we try what spherical glass enables him to see these lines distinctly and clearly; this glass is the measure of the refraction of the vertical meridian, and therefore also of the astigmatism.

FIG. 76.

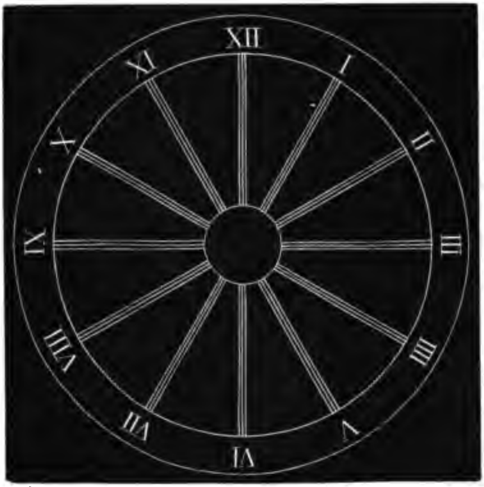
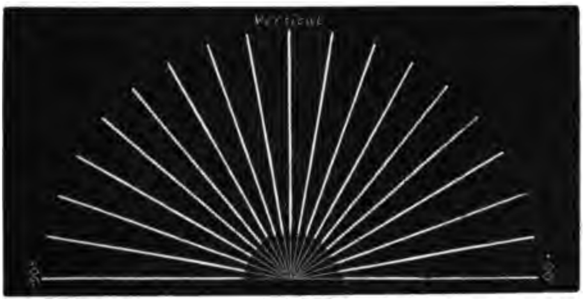


FIG. 77.



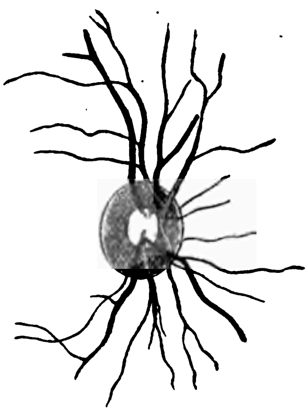
To obtain reliable results, the eye *must* be thoroughly under the influence of atropine.

Supposing lines from 12 to 6 be clearly seen, but that with a weak convex glass they are blurred; and

that on looking at lines 3 to 9, no convex glass improves their clearness, while -1 D. renders them quite distinct, the case is one of simple myopic astigmatism.

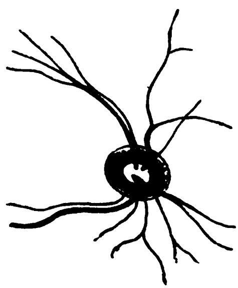
With the ophthalmoscope the astigmatism may also be recognised. 1st. With the *indirect* method we find that the shape of the disc, instead of being circular, is more or less oval, changing its shape as the objective, which must be held exactly perpendicular, is withdrawn. 2nd. With the *direct* method we find that the disc appears oval, the long axis of the oval corre-

FIG. 78.*



Erect image.

FIG. 79.



Indirect image.

sponding to the meridian of greatest refraction. Figs. 78 and 79 show the same disc as seen by the direct and indirect examination.

It is, however, the difference in degree of the clear-

* I have to thank Mr Nettleship for the electros from woodcuts, in his work on 'Diseases of the Eye.'

ness of the retinal vessels, that is to be taken as the guide, not only of the chief meridians, but also of the kind and amount of error. To detect this we take notice first of the lateral margins of the disc, and of a vessel running in the vertical direction, and find out the *strongest* positive, or the *weakest* negative glass, with which these are distinctly seen, using a refracting ophthalmoscope. We then take a horizontal vessel with the upper and lower margins of the disc, and estimate their refraction in the same manner. Thus a vessel going upwards is first taken; it is seen well with a convex 1, the horizontal meridian therefore is hypermetropic 1 D. A horizontal vessel is now looked at and can be best seen with concave 1, showing that the vertical meridian is myopic to one dioptre; the case is, therefore, one of mixed astigmatism. Some observers are able to estimate and order the proper correcting glasses by this method alone. I should, however, be exceedingly sorry to trust to it entirely.

3rd. *Retinoscopy.* This is, I think, without doubt the most valuable and trustworthy of all the objective methods. The patient being fully atropized, the principal axes can be seen at a glance, and the proper glasses for correcting the error easily found, by anyone who has taken the trouble to familiarise himself with this method of examination. For a full description of retinoscopy, the reader must refer to the chapter on that subject.

Astigmatism requires for its correction a cylindrical glass, that is, one which instead of being the segment

of a sphere, as is a spherical glass, is the segment of a cylinder. It may be either concave or convex, and the result upon rays will be, that those which pass through the cylinder parallel to its axis, undergo no refraction; all other rays are refracted, those most so, which pass at right angles to the cylinder. It thus possesses the power of exactly neutralising the astigmatism.

On referring back to Fig. 71, which represents a case of simple hypermetropic astigmatism, the vertical meridian being emmetropic and the horizontal meridian hypermetropic, it will be seen that a convex cylinder can be found, which with its axis vertical will increase the refraction of rays passing through the horizontal meridian, so that they meet exactly on the retina. Suppose the glass required be + 1 D. cylinder, this not only corrects, but is itself a measure of the astigmatism. If a patient with astigmatism of 1 D. be able to read $\frac{6}{12}$ at the distant type and with the cylinder + 1 D., axis vertical $\frac{6}{6}$, it may be expressed in the following manner: $\frac{6}{12}$ + 1 D. cy. axis vert. = $\frac{6}{6}$

Fig. 72 represents compound hypermetropic astigmatism. We find out the refraction of each chief meridian by retinoscopy or the clock face. Assuming then, the vertical meridian to be + 1 D., and the horizontal +2 D., if we place our positive cylinder + 1 D. with its axis vertical, we shall have corrected the astigmatism, and the error will be reduced to one of simple hypermetropia, requiring for its correction +1 D. sphere. This combination of sphere + 1 D. with

cylinder + 1 D. axis vertical, is made in one glass, by the optician grinding upon one side the sphere + 1 D., and on the other the cylinder + 1 D. The lens thus formed is called a spherico-cylindrical lens.

Fig. 73 represents simple myopic astigmatism, in which the vertical meridian is myopic and the horizontal emmetropic. To correct this error it is necessary to cause the rays which pass through the vertical meridian, to be so refracted that they meet *at*, instead of *in front of*, the retina. Here it is obvious that a negative cylinder with its axis horizontal will accomplish this object.

Fig. 74 represents compound myopic astigmatism. Both sets of rays focus in front of the retina, one set in advance of the other. This is corrected by putting back the posterior focus by a negative sphere which reduces the case to one of simple myopic astigmatism, which is corrected by a negative cylinder. This glass is called a negative spherico-cylindrical lens.

Fig. 75 represents mixed astigmatism. One set of rays focus in front of the retina, the other set behind it. The difference between these is the amount of astigmatism, and may be corrected in three different ways. Thus supposing the vertical meridian myopic 1 D., and the horizontal hypermetropic 1 D., the correction may be made by —1 D. cylinder, axis horizontal, which puts back the vertical rays so as to focus on the retina, combined with a + 1 D. cylinder axis vertical, which brings forward the horizontal rays to the retina. This compound lens is called a concavo-convex cylinder. There are, however, some diffi-

culties in using this method of correction; the axes of the cylinders have to be arranged with such exactness, that the slightest variation may upset the whole result. Besides, it is difficult when using such a combination at the distant type, to make alterations with the same facility with which one does other combinations. Moreover, during the grinding very great care is required of the optician, so that either of the following plans seems preferable. By a minus concave spherical glass of 1 D., combined with a convex cylinder of 2 D. axis vertical, or by a +1 D. sphere combined with − 2 D. cylinder axis horizontal.

Having found out by one of these numerous methods, the refraction of the two chief meridians, we confirm the result by trying the patient at the distant type with the combination so found, making any slight alterations which may be necessary. The patient must be allowed a week, to thoroughly recover from the atropine, and the result then finally confirmed, remembering that we shall have to reduce the convex and increase the concave glass slightly; spectacles are then ordered, which must be worn constantly.

We frequently have to be satisfied with glasses which do not raise the vision to $\frac{6}{6}$, and if such have been carefully chosen, we often find that after they have been worn for some time the vision improves, due no doubt to the retina becoming more sensitive to well-defined images, a condition of things to which it was previously unaccustomed.

In ordering glasses for astigmatism, we must be

careful to give the exact axis of each cylinder; opticians supply us with convenient forms, having a diagram of a frame marked in degrees; we indicate the axis by drawing a line through this diagram.

The **ophthalmometer of Javal and Schiötz** is an instrument for measuring the amount of corneal astigmatism. Scientifically it may be of much value, as by it we are enabled to separate astigmatism due to the cornea, from that due to the lens, but the price will prevent its coming into general use, especially, as we possess so many other methods by which astigmatism may be estimated, and probably the separation of the two forms of astigmatism is a disadvantage practically, when we are seeking to correct the defect.

With the ophthalmometer two objects are reflected on to the cornea of the observed eye; these objects are of white enamel, one quadrilateral in shape, the other of the same size, except that on one side it is cut out into five steps; these two objects slide on a semicircular arm, which rotates round the tube through which the observer looks, one object on either side of the tube; the observer looking through this tube, which contains a combination of convex glasses and a bi-refracting prism, sees four magnified images in a line on the cornea under examination. First find out the meridian of least refraction, this we are able to do by finding the position of the semicircular arm, in which the two central images (one quadrilateral, the other with steps) are furthest apart. We slide the two objects together until we see the two

central images on the observed cornea just touch, the lowest step of the one with the side of the other; this then is the meridian of least refraction, and we note it down as such, now turn the arm at right angles to this meridian, and notice the amount of overlapping of the two central images, each step in the one figure that is overlapped by the quadrilateral one, is equal to one dioptre; thus if it overlap three steps, there is a difference of 3 D. between the meridians of least and greatest refraction; we know this to be the meridian of greatest refraction, because it is at right angles to the one first found.

As there are only five steps, when there is a difference of 5 D. between the two meridians, the one figure will exactly overlap the other; for higher degrees we have to calculate how much the figure with the steps, projects beyond the quadrilateral figure, or we may place in the tube a stronger bi-refracting prism, then each step may be counted as two dioptres instead of one.

Nordenson has obtained some interesting statistics with this ophthalmometer ('Ophthalmic Review' for July, 1883) in 226 school children. As a result of these statistics he is of opinion:

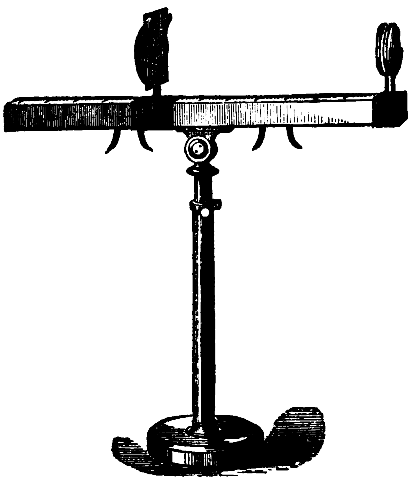
1st. That the correction of corneal astigmatism by means of the lens in young persons is the rule.

2nd. That corneal astigmatism amounting to one and a half dioptres, is incompatible with normal acuteness of vision.

His observations add also to the opinion of Javal, that astigmatism predisposes to myopia.

Tweedy's optometer affords an easy method of estimating the refraction in astigmatism. It consists essentially of a plate carrying the figure of a dial, marked with fine dark radiating lines at angles of 15° with each other; the plate is attached to a horizontal bar half a metre long, divided into centimetres on which it may be made to slide; at the proximal end of

FIG. 80.



the bar is a semi-circular clip, marked with degrees corresponding to those on the dial, and intended to hold the cylindrical lens. In order to use the instrument properly, the following instructions must be strictly complied with:

1st. The eye about to be examined having previously

been placed completely under atropine, and made artificially myopic to about 4 D. by means of a strong convex lens placed in a spectacle frame, and the opposite eye excluded by an opaque disc, the patient should sit down before the instrument, place the eye with the lens before it close to the clip, and with the head erect should look straight in front at the radiating lines of the dial.

2ndly. The dial having first been removed beyond the point of distinct vision, should then be gradually approximated along the bar, until at least one of the lines is clearly and distinctly seen; after this the dial should on no account be moved, but its distance from the eye accurately noted.

If all the radiating lines come into view with equal clearness at the same time, there is but slight astigmatism, but if whilst one line is clearly seen, that at right angles to it is blurred, there is astigmatism, which may be corrected, by placing in the semicircular clip a concave cylindrical lens with its axis parallel to the blurred line, or at right angles to that first distinctly seen.

From the result of (2) we learn (*a*) the direction of the two principal meridians, of maximum and minimum refraction; (*b*) the presence or absence of hypermetropia or myopia and the degree; (*c*) the presence or absence of abnormal regular astigmatism, including its direction and degree. (*a*) The meridian of greatest refraction is parallel to the line seen at the greatest distance of distinct vision, while the meridian of least refraction is always at right angles to it. (*b*) The

presence or absence of ametropia is determined by the distance at which the radiating lines are clearly seen. If there be emmetropia, the lines will be seen exactly at the distance of the focal length of the lens employed to produce the artificial myopia; if there be hypermetropia, the lines will be seen beyond that point, if myopia within. The degree of ametropia may be estimated by the following calculation: The greatest distance of distinct vision, minus the focal length of the lens, divided by multiple of these numbers, equals the degree of ametropia.

(*c*) If, however, there be astigmatism, the above calculation will give the refraction for the meridian of least refraction only; the degree of astigmatism will be represented by the focal length of the weakest concave cylinder, which, placed with its axis parallel to the blurred line, makes this line as clear and distinct as that first seen. The whole ametropia may then be corrected by combining the spherical lens required for the correction of the meridian of least refraction, with the weakest cylindrical lens, which by actual experimentation has been found sufficient to correct the astigmatism.

The **stenopaic slit**, which consists of a metal disc having an oblong opening in it, about 2 mm. broad, is used by some observers for working out cases of astigmatism. The disc is placed in a trial frame in front of the eye we wish to examine; and while the patient looks steadily at the distant type the disc is slowly rotated, so that the slit is brought successively in front of each meridian, the position in which the best vision

is obtained is noted, we then try convex and concave glasses in front of the slit, to see if any improvement take place. The slit is now in line with one of the chief meridians; let us turn the disc round 90°, so that the slit may occupy the position of the other chief meridian, and find out what glass most improves vision. Thus, supposing the slit in the vertical direction, the patient reads $\frac{6}{6}$, while convex glasses in front of the slit make it indistinct, the vertical meridian is emmetropic; now turn the slit so that it is horizontal, the patient reads $\frac{6}{12}$, but with + 2 D. in front $\frac{6}{6}$, the horizontal meridian is then hypermetropic; the case is therefore one of simple hypermetropic astigmatism requiring for its correction + 2 D. cylinder axis vertical. On looking through the slit, placed between the principal meridians, circles of diffusion are formed, and the object has the appearance of being drawn out in the direction of the slit.

Dr Tempest Anderson, of York, has invented an ingenious instrument, by which astigmatism may be estimated in a subjective manner; an image of an illuminated radiating screen is thrown on the retina, and is visible to the oculist, the position of the screen on a graduated bar shows the refraction.

The inventor claims for his instrument the following advantages:

1. The observations and measurements are made by the observer, and are entirely independent of the patient's sensations, though these may be used as an adjunct if wished.

2. An image thrown on the retina being used as an

object, the error arising from the vessels or optic nerve being before or behind the retina is avoided.

3. The refraction and accommodation of the observer does not affect the result. It is only necessary that he should be able to see, whether certain lines are sharply defined.

In addition to the methods already described for estimating astigmatism, many others are known.

See Cases 3, 4, 5, 6, 7, 8, 9, page 97, &c.; also 20 and 21, page 214.

Anisometropia

Anisometropia (*α* priv *ἴσος*, equal; *μέτρον*, measure; *ὤψ*, the eye) is the term applied to cases which frequently occur, where the two eyes vary in their refraction. The defect is usually congenital, but it may be acquired, as in aphakia or loss of accommodation in one eye. One eye may be emmetropic, the other myopic or hypermetropic; or one more myopic, hypermetropic, or astigmatic than the other. When the difference is not very great (1 or 1·5 D.), and vision in both eyes is good, we may give each eye its correction; for so long as the eye whose refraction is the most defective still co-operates in binocular vision, sight is improved thereby. Especially is this full correction useful in cases of myopia with divergent strabismus, the increased stimulus to binocular vision being sometimes sufficient to prevent the squint. When one eye is emmetropic and the other myopic, no glass will probably be required, the emmetropic eye being

used for distance, the myopic for reading, &c. When the difference in the refraction is greater than 1·5 D. we may have to be satisfied with partially correcting the difference, and this result can only be arrived at by trying each case, some people tolerating a much fuller correction than others. Frequently, no attempt can be made to correct the two eyes, and then we generally give glasses that suit the best eye. In cases of aphakia, &c., where one eye is used almost entirely, while the other though defective still possesses vision, it is an excellent plan to insist on the latter being daily exercised with a suitable glass, the good eye being at the same time covered; by this means, the bad eye is prevented from becoming amblyopic, and can at any time be utilised should occasion require.

See Cases 4, page 98, 14 and 15, page 209.

CHAPTER VIII

PRESBYOPIA. Pr. (πρέσβυς, old; ὤψ, eye)

WITH advancing age many changes take place in the eye. The acuteness of vision becomes less, owing partly to a loss of transparency in the media, and partly also to a diminution in the perceptive and conductive powers of the retina and the optic nerve. At thirty years the acuteness of vision is almost unaltered, the bottom line of the distant type being read at a little over 6 metres; at forty it can still be read at 6 metres, but after this time it diminishes regularly, so that by the eightieth year vision has decreased to one half. In addition to these changes, the *accommodation* gradually diminishes from a very early period, the near point slowly but steadily receding. This change in the accommodation occurs in all eyes whatever their refraction, and is due to an increased firmness of the lens, whereby its elasticity is lessened; and perhaps also in some slight degree to loss of power in the ciliary muscle due to advancing age. The lens also approaches the cornea, and becomes somewhat flatter. This failure of the accommodation begins as early as the tenth year, at an age when all the functions of the body are still developing.

Fig. 81.

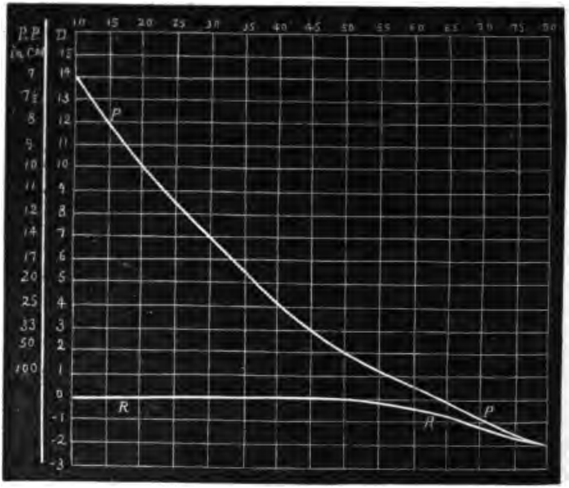


Diagram from Donders, showing the course of accommodation in an emmetropic eye. The figures at the top of the diagram indicate the age, those at the side the amount of accommodation and the p. p. in centimetres; the oblique line represents the course of the punctum proximum, and the horizontal line that of the punctum remotum; the space between the two lines gives the amplitude of accommodation. From this diagram we can calculate the amplitude of accommodation possessed at any age.

So soon as the binocular near point, has receded beyond the distance at which we are accustomed to read and write, do we become restricted in our work. Donders has fixed this point at 22 cm.

Presbyopia, therefore, may be arbitrarily stated to exist, when the binocular near point has receded to 22 cm., and this occurs usually in the emmetrope about the age of forty-five. Because in order to see at 22

cm. a positive refractive power of 4·5 is necessary ($\frac{100}{22}=4{\cdot}5$), at the age of forty the eye possesses just this amount of refractive power, but if the eye has not so much accommodation, then we must give such a convex glass, which, added to it, brings up the positive refraction to 4·5 D.; for example at the age of fifty-five when the eye possesses only 1·5 D. of accommodation, we give a convex glass of 3 D., because 1·5 D. +3 D. =4·5 D (see table, page 167).

To find the punctum proximum of an emmetrope we have only to divide the number of dioptres of accommodation which he possesses into 100 cm. Thus at twenty there are 10 D. of accommodation; this would give us 10 cm. as the near point. At forty there are 5 D., in which case the near point is 20 cm.

When the punctum proximum has receded to 22 cm.; the point at which it is convenient to read is considerably further away, since for sustained vision only about half of the accommodation can be used. Thus a person with 4 D. of accommodation would have his near point at 25 cm. with the maximum contraction of his ciliary muscle, and if he can only comfortably use about half this for continuous work, his reading point would be 50 cm.; this is far too great a distance. We bring back the near point by convex glasses, which is practically the same as increasing the accommodation.

Although we have said, that only about one half of the accommodation can be used for sustained vision, this is not absolutely correct, the amount which must be in reserve, varies much with different individuals;

thus in one case with a surplus of 1 D. much work can be done, whereas, in another a surplus of 3 or 4 D. is necessary.

Symptoms.—The presbyope sees well at a distance, but has difficulty in maintaining clear vision for near objects, the chief symptoms are a feeling of weariness in the eyes after reading, especially in the evenings, small objects being less easily seen than formerly, because, having to be held further from the eye they subtend a smaller visual angle. The patient seeks a strong light, or places the lamp he is using between his eye and the book, by doing this he causes his pupils to contract and so lessens his circles of diffusion, he avoids small print, and holds the book or work further away. These symptoms are due to a recession of the near point, and if asthenopia occur, this may be dependent upon a disturbance of the balance between accommodation and convergence; the convergence being the same for any given point, a much greater accommodative effort is necessary, than was formerly the case.

The **treatment** of presbyopia consists, in prescribing convex spectacles for reading and near work, so as to bring back the near point to a convenient distance. In uncomplicated presbyopia distant vision is, of course good. We have only to remember to add on 1 D. for every five years up to sixty, commencing at the age of forty-five.

The following table gives approximately the strength of glasses required by emmetropes at different ages, to bring back their punctum proximum to 22 cm.:

Age.		Amount of accommodation possessed at that age.		The near point.		Glass required to bring back p.p. to 22 c.m.
45	...	3·5 D.	...	28 c.m.	...	+1 D.
50	...	2·5 „	...	43 „	...	+2 D.
55	...	1·5 „	...	67 „	...	+3 D.
60	...	·5 „	...	200 „	...	+4 D.
70	...	·0 „	...	infinity.	...	+5 D.

To find the glass required in presbyopia, we subtract the glass which represents the receded near point from the glass whose focus represents the point we wish to make the near point. Thus the near poiut has receded to 50 cm.; the glass representing this point is +2 D. ($\frac{100}{50} = 2$). We wish to bring the near point to 20 cm.; this would be +5 D. ($\frac{100}{20} = 5$); hence +2 D. from +5 D. gives +3 D. as the glass required.

Although glasses can be frequently thus ordered by a sort of rule of thumb, it is always well to bear in mind, that the definition given of presbyopia with reference to its near point is entirely an arbitrary one, and that we must take into account the distance at which the individual has been accustomed to read and work. In this there is great variety. Many small people work and read at 20 cm., whereas, very tall people may be uncomfortable unless the book they are reading is 35 or 40 cm. away. The distance for which the presbyope requires spectacles will also vary much according to the occupation for which he requires them. There exists a popular prejudice against the use of strong glasses, all sorts of maladies having been attributed to their use; this prejudice is quite unfounded, the only possible harm that can arise from

wearing too strong glasses is that the patient may suffer from asthenopia.

Before ordering glasses for presbyopia, it is necessary to try the patient's distant vision, so that any hypermetropia or myopia may be recognised. If hypermetropia exist, the amount must be added to the presbyopic glass; if myopia, it must be subtracted. Thus a patient with hypermetropia requiring +2 D. for its correction, at the age of forty-five will require + 3 D. for reading (H. 2D. + Pr. 1 D. = + 3 D.).

A myopia of 1 D., will require no glass at the age of forty-five (M. 1 D. + Pr. 1 D. = O.). If the myopia be 4·5 D. then the patient can never require a glass for presbyopia, his far point being 22 cm. always. His near point may recede to this distance when all accommodation is lost, but he will still be able to read at that distance, though at that distance only.

Donders thinks, that as age advances the refraction of the eye diminishes, in other words, the eye if emmetropic becomes hypermetropic (called acquired hypermetropia). The myopic eye becomes less myopic, so that a real improvement in vision takes place. The hypermetropic eye becomes more hypermetropic. This change takes place at a regular rate in all eyes, at fifty-five the refraction has diminished ·25 D., at sixty-five ·75 D., at sixty-eight 1 D., and at eighty as much as 2·5 D. Thus at eighty an emmetrope will have acquired 2·5 D. of hypermetropia, and will therefore require a convex glass of 2·5 D. for distant objects to be seen clearly. A myope of 2·5 D. would at eighty

have become emmetropic, and require no glass for distance. A hypermetrope of 2·5 D. will add on to his defect 2·5 D., and will require a + 5 D. for distance. This change is due to an alteration which takes place in the structure of the crystalline lens, by which its refractive power is diminished.

While admitting that many old people, who have been assumed to be emmetropic, see distant objects better with a convex glass, some observers say, that this is due to a small amount of latent hypermetropia becoming manifest, and not to any decrease in the refractive power of the eye.

Dr Scheffler some years ago proposed the use of what he called orthoscopic lenses, that is, lenses with two elements, a sphere and a prism so proportioned, that the amount of accommodation and convergence should exactly correspond. Thus in the case of a presbyope, aged fifty, requiring + 2 D., to make him read comfortably at 30 cm., it would be combined with a prism base inwards, that would bring the optic axes exactly to that point, the effect being complete repose both for the accommodation and convergence. The results, however, are not so good as might have been hoped; the glasses are too heavy, and on looking at a flat surface some distortion is produced. Nevertheless, cases do occur, in which though the presbyopia is corrected, the patient after reading a short time complains of asthenopia. Such cases are frequently at once and completely relieved by combining with their spheres, prisms of 2° or 3° with their bases inwards, or by having the lenses decentred, so that he

looks through the outer part of them, making thereby convex prisms.

Care should moreover be used to see that the glasses are properly centred, unless they have been ordered otherwise, and that the frames are not too broad, in which case the lenses form prisms with their bases outwards, and are very apt to give rise to asthenopia, by disturbing the relations between convergence and accommodation.

In cases where the convex glasses have frequently to be changed for stronger ones, "glaucoma" should be carefully looked for; and if any symptoms of it appear, no glasses must be allowed, as it is of the greatest importance to avoid all possible tension.

The commencement of cataract also appears to hasten presbyopia.

In each case of presbyopia, first test the patient's distant vision, so as to detect any hypermetropia, myopia or astigmatism, and having recorded this, we add the glass which he requires for his presbyopia and try him with the reading type, if they suit we direct the patient to read with them for half an hour or so; if found satisfactory we order spectacles of this strength.

See Cases 12, 16, 17, and 18, pages 208, 212 and 213.

Paralysis of the Accommodation

Paralysis of the accommodation arises from loss of power in the ciliary muscle, due to paralysis of the third nerve, or of that branch of it which supplies the

muscle of accommodation and the circular fibres of the iris. Cases do occasionally occur, though very rarely, of paralysis of the ciliary muscle, not involving the constrictor pupillæ. Generally both eyes are affected, frequently however only one.

Causes.—Atropine is the most common cause, but it may be due to diphtheria, fever, any complaint of a lowering character, cerebral trouble, syphilis, or some reflex irritation, *e.g.* decayed teeth, &c.; the cause may however not be apparent. When the whole third nerve is involved, ptosis, external strabismus, &c. occur; but in those cases where the branch supplying the ciliary muscle and the circular fibres of the iris is alone implicated, the indicating symptoms are, asthenopia, dilatation of the pupil, and loss of the power of accommodation, whereby the patient though able to see distant objects well (if emmetropic) is unable to read or do any near work. If hypermetropic, both near and distant vision will be impaired; if myopic he is able to see only at his far point. We try the patient at the distant type, and if he is able to see $\frac{6}{6}$ and yet is not able to read near type, the diagnosis is obvious.

Treatment consists in giving such convex glasses as enable him to read. In order to bring the emmetrope's far point from infinity to 35 cm. + 3 D. is required ($\frac{100}{35}=3$ nearly). We must bear in mind that by encouraging the action of the ciliary muscle, we hasten the patient's recovery; this we do by giving the *weakest* convex glasses with which he is able to read, changing them for weaker ones occasionally

as the ciliary muscle gains strength. Sulphate of eserine in solution grs. j to ℥j, causes contraction of the ciliary muscle as well as of the iris, and temporarily relieves the symptoms; I think much good sometimes results from its use once every other day for some weeks, the ciliary muscle being made to contract, relaxing again as the effect of the myotic passes off. Attention must be paid to the general health, iodide of potassium or nerve tonics being given, when indicated by the cause.

See Case 13, page 208.

Spasm of the Accommodation

Spasm of the accommodation is due to excessive contraction of the ciliary muscle, and occasionally occurs in eyes whatever their refraction, though most commonly in cases of hypermetropia and low myopia. It may occur as a result of uncorrected ametropia, or in emmetropia from overwork, especially when such work has been done in a bad light. It gives rise to symptoms of asthenopia, and sometimes to myosis, due to excessive contraction of the circular fibres of the iris. In emmetropia we may get symptoms of myopia owing to the parallel rays coming to a focus in front of the retina. In hypermetropia the symptoms may also simulate myopia, and for this we should always be on our guard. I have on several occasions seen hypermetropes going about wearing concave glasses, to correct their supposed shortsightedness. In

myopia the real defect is apparently increased, and we might be in danger of ordering too strong concave glasses, &c. For these reasons the systematic use of atropine in young people (whereby one is enabled to estimate and record the exact state of the refraction) cannot be too strongly insisted upon. The treatment, where spasm of the ciliary muscle is suspected, is to drop into the eyes three times a day, a solution of atropine grs. iv to ℥j for two or three weeks, by which means we give the eyes complete rest; to correct any ametropia that may exist; and to attend to the patient's general health, administering tonics if necessary.

A few cases of acute spasm of the accommodation have been recorded which resisted the treatment by atropine, the spasm though relaxed by this means, returned as soon as the atropine was discontinued.

See Case 1, page 96.

CHAPTER IX

STRABISMUS (στρέφω, I turn aside)

STRABISMUS exists when there is a deviation in the direction of the eyes, so that the visual axes are not directed to the same object.

The points to note when a case of strabismus presents itself, are—

1. Is the strabismus real or apparent?
2. If real, to which variety does it belong?
3. Which is the deviating eye?
4. In which direction is the deviation?
5. What is the degree of the deviation?
6. What is the cause of the strabismus?

Apparent may be mistaken for *real* strabismus, by confusing the *visual axis* (which is the line passing from the macula, through the nodal point to the object looked at), with the optic axis (which passes from the inner side of the macula, through the nodal point and the centre of the cornea); these two axes form an angle of about 5° in emmetropia (Fig. 82). This angle is called the angle *a*, and when thus formed by the crossing of the visual and optic axes, it is said to be *positive*.

In hypermetropia (Fig. 83) the angle α increases with the degree of hypermetropia, and if it be high

FIG. 82.

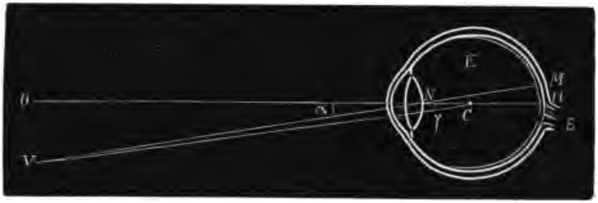


FIG. 83.

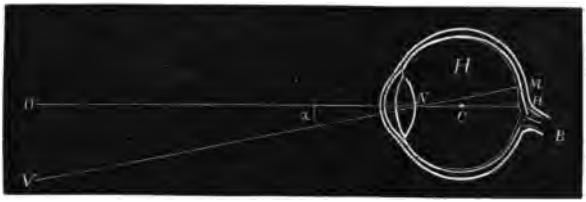


FIG. 84.

M. The macula. N. The nodal point. B. Optic nerve. V. The object. V M. The visual axis. O H. The optic axis. α. the angle alpha formed between the visual and optic axes. C. The centre of rotation of the eyeball situated on the optic axis. γ. The angle gamma (Fig. 82) formed at the centre of rotation of the eyeball, by the optic axis and a line drawn from the centre to the object looked at.

may attain 7°, 8°, or even more; this large angle gives to the eyes an appearance of divergence.

In myopia (Fig. 84) the angle α decreases, and in high myopia the visual axis may approach the optic axis, so that the angle α is very small, or it may coincide with it, when no angle is formed, or even be altogether on the outer side of it, when the angle is said to be *negative*. This small angle α gives to the eyes an appearance of convergence.*

In order to find out the variety to which our case of strabismus belongs, as well as to decide which is the deviating eye, we direct the patient to look at an object held about a metre in front of him, then gradually bring this object nearer to him, so as to call into action the accommodation; if both visual axes continue to be directed steadily towards the object as it is made to approach the eyes, the case is one of *apparent* strabismus; but if one eye fixes it, while the other after following it up to a certain distance, suddenly deviates inwards or outwards, the condition is spoken of as *concomitant* (convergent or divergent) strabismus; or both eyes may follow the object up to a certain point, when one stops, after perhaps making a few jerking oscillating movements; we then speak of it as belonging to the *paralytic* variety of strabismus. Again, having covered one eye with a card, or what is better with an opaque glass disc, which, while preventing the patient seeing with that eye, yet allows us to see the move-

* Another angle sometimes mentioned is the angle γ, which is the angle formed at the centre of rotation of the eye by the optic axis, and a line drawn from this centre to the object looked at. Shown in Fig. 82.

ments that take place behind it; we direct him to fix with the other eye some object, such as a pencil held about half a metre in front of him. If the covered eye make a movement inwards, the squint is real, and this movement is called the *primary deviation*. If now the fixing eye be covered, the squinting one uncovered and made to fix the object, the first eye, which is now excluded from vision may make a movement inwards; this movement of the sound eye is called the *secondary deviation*.

When the primary and secondary deviations are equal the squint is said to be *concomitant*.

The range of movement in concomitant squint is as great as in emmetropic eyes, it is simply displaced; in the paralytic form, the movements of the squinting eye are usually much curtailed; this we easily detect by holding up the finger about 50 cm. in front of the patient and directing him, while keeping the head still, to follow the movements of the finger which is moved to either side, and then up and down. In the concomitant form, the squinting eye will almost exactly accompany the other, the visual lines being at the same angle except perhaps in the extreme periphery, whereas in the paralytic form, the movement in one eye will stop at a certain point, while the other eye continues to follow the finger.

When either eye fixes indifferently, the vision being equally good in both, it is called *alternating strabismus*. *Monolateral* or *constant* when the same eye always squints; the vision in the squinting eye is usually below that in the fixing one.

Periodic when it only comes on occasionally, as after looking for some time at near objects. If judiciously treated this variety can be cured without operation, if neglected it generally passes on into one of the constant forms.

In concomitant strabismus the primary and secondary deviations are equal. In the paralytic form the secondary deviation usually exceeds the primary.

There are several ways by which we may estimate the amount of the deviation. We may indicate it in the form of a diagram; the position of the pupil to the internal canthus when looking as far as possible to one side, will show the extreme range of the eye inwards, then direct the patient to look in the opposite direction, so that we may find the extreme range outwards, this we indicate by the position of the outer edge of the cornea, with the external canthus; our diagram must of course include both eyes, so that we may judge of their relative range of movement.

The strabismometer (Fig. 85) consists of a handle, supporting a small ivory plate, shaped to the lower lid and having on it a scale by which we measure the amount of deviation of the centre of the pupil. This is an easy method of measuring the strabismus, but is not to be depended upon.

The measurement of the *angle of the strabismus*, is the only reliable and exact method of recording the amount of squint. Landolt defines this angle, as that which the visual axis makes, with the direction it should have, in a normal state.

For this measurement we require a perimeter, in

front of which we seat the patient, with the quadrant placed according to the kind of squint we are about to

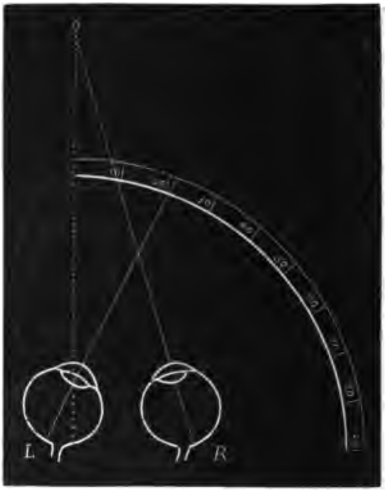
FIG. 85.

Strabisometer.

measure; if it be a convergent or divergent one, then the quadrant is placed horizontally. The patient being seated so that his deviating eye is in the centre of the instrument; we direct him to fix with both eyes some distant object (o, Fig. 86) placed in a line with the centre of the perimeter; a lighted candle is moved gradually along the inside of the quadrant from the centre of the instrument outwards; the observer, following the movement of the candle with his head, stops as soon as the reflection of the candle on the cornea of the squinting eye occupies the centre of its pupil, this gives us the direction of the optic axis, what we really

wanted, was the direction of the visual axis, but for all practical purposes the former is sufficient. The

FIG. 86.



degree is read off the quadrant at the point where the candle was stopped and this result recorded. We must next measure the angle of deviation for near vision, by requesting the patient to look at the centre of the perimeter, proceeding with the candle as before, and recording the result.

Strabismus may be concomitant or paralytic.

The concomitant variety is invariably connected with errors of refraction; in it the deviating eye maintains unaltered its relative position to its fellow, in every direction of vision; whereas in the paralytic variety the movements of the deviating eye are much curtailed.

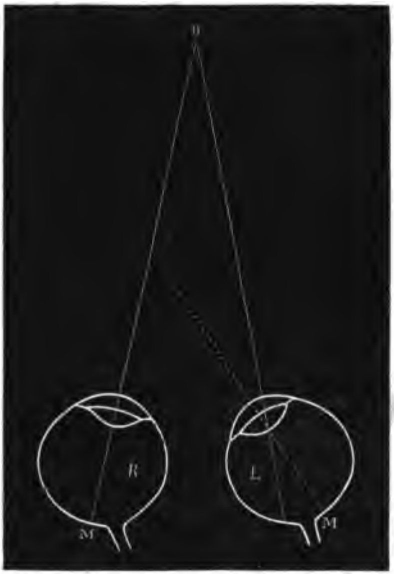
Concomitant strabismus is intimately connected with hypermetropia and myopia, it may be—

Convergent.

Divergent.

Convergent strabismus.—On looking at any object one eye only is directed to it; the other, as the name implies, looks inwards, so that the metrical angle is much greater in the deviating, than in the fixing eye.

FIG. 87.



R. Right eye directed to object O. L. Left eye deviating inwards. M. Macula.

It is almost always due to hypermetropia, probably at least 80 per cent. of the whole, being due to this

cause, its method of production depends upon the intimate connection that exists between accommodation and convergence.

The convergence is most marked when looking at near objects; sometimes there may be no squint when distant objects are viewed.

A hypermetropic person, requires to use some of his accommodation for distant objects; for near objects he must, of course, use still more, since for every increase in the accommodation, there is a desire for a certain increasing degree of convergence. Thus an emmetropic individual, accommodating for an object at 30 cm., would at the same time converge for that particular point. If the individual were hypermetropic to the extent of 4 D. he would probably possess the same amount of accommodation as if emmetropic, we will suppose 8 D., whilst of these, one half (4 D.) would be required to enable him to bring parallel rays to a focus on the retina; he would have the tendency at the same time to use half his convergence. Thus for distant objects he would have an inclination to converge, his internal recti acting, and it is only by the increased tension of the external recti, called into action by the desire which all eyes possess for singleness of vision, that convergence is prevented. The more we converge the more can we accommodate; so that on looking at near objects—which means an increase of the accommodation—an increased tendency to convergence is produced. Therefore, one of two things must occur; either the patient must see indistinctly by not accommodating

sufficiently, or one eye must be allowed to converge. Some patients with hypermetropia prefer binocular indistinct vision, others, single clear vision with a squint.

One occasionally finds an individual who can thus choose which he will do; we are trying his acuteness of vision at the distant type perhaps, he stops at some place, we will suppose $\frac{6}{12}$, and says that he is unable to read the next two lines unless he squint. The accommodation necessary to read $\frac{6}{6}$, makes a heavier call on the convergence than can be borne; such a case forms a good illustration of the manner in which convergent strabismus is produced in a hypermetrope.

Hence, if the impulse to see distinctly, is greater than the desire to retain binocular vision, one eye yields, and squint occurs; at first diplopia follows the convergence, and is always in the opposite direction to the deviation. Possibly the convergence of the deviating eye is increased by the desire, that the weaker image may be made still weaker, by falling on a more peripheral part of the retina. At first the diplopia may be very annoying, but by degrees the sensorium learns to suppress the image of the weaker eye, which after a time becomes amblyopic. The earlier the age at which the squint appears, the sooner does the sight in the deviating eye thus deteriorate.

In high degrees of hypermetropia, when no amount of accommodation can make vision distinct, squint is less likely to occur. It is usually, therefore, in cases of from 2 to 4 D. that convergent strabismus is most

frequently met with, and it generally makes its appearance about the fifth or sixth year, so soon in fact, as the child begins to use its accommodation much for near objects. Anxious parents frequently have all sorts of excellent reasons to which they attribute the defect; they say that the child has been imitating its playmate, or that the nurse did something which caused it to squint, perhaps, by making the child look too much, or too constantly in one direction.

Any cause which by rendering the image in one eye, less distinct than that in the other, as nebulæ, ulcers of the cornea, a difference in the refraction of the two eyes, or even wearing a shade for a few days for some trivial complaint, may, where hypermetropia is present, combine to produce strabismus; the impulse for binocular vision is lessened, and the eye in which the fainter image is formed, converges.

It is thus seen that convergent strabismus gradually destroys binocular vision. In cases of hypermetropia, where binocular vision does not exist owing to great difference in the refraction of the two eyes, divergent strabismus may occur.

This intimate connection between accommodation and convergence, together with the method of the production of strabismus, will be more easily understood by carrying out some such simple experiments as the following. We will assume the observer to be emmetropic; the strongest concave glass with which he, having binocular vision and being at a distance of six metres, can still read $\frac{6}{6}$, is the measure of the

relative accommodation. The *absolute accommodation* is measured by the strongest concave glass, with which each eye separately can read $\frac{6}{6}$. In my own case, with -4 D. before each eye, $\frac{6}{6}$ can be seen singly and distinctly, $-4\cdot5$ D. renders it indistinct, and each increase in the glass increases the indistinctness, but produces no diplopia. Separately each eye can overcome -7 D. Armed with -4 D. before each eye, I am able to see $\frac{6}{6}$ distinctly, using of course 4 D. of my accommodation; if a colored glass be placed before one eye, homonymous diplopia at once appears, proving that one eye has deviated inwards; with -3 D. and the colored glass, squint was produced, but with no weaker concave glass.

On repeating the experiment in an individual with $\cdot5$ D. of myopic astigmatism in one eye, and emmetropia in the other, -2 D. before each eye was the strongest glass with which $\frac{6}{6}$ could be seen clearly and singly, $-2\cdot5$ D. did not render it indistinct, but produced diplopia. The absolute accommodation for each eye amounted to 6 D. With -2 D. before each eye the colored glass was placed before the astigmatic one, and diplopia was produced. With -1 D. and the colored glass the result was the same, except that the two images were nearer together. With $-\cdot5$ D. actual diplopia was not produced.

These experiments require but little explanation. In my own case, when using 4 D. of accommodation, I have the tendency also to use a corresponding amount of convergence; I am conscious of this muscular disturbance by the effort I make and by a

feeling amounting almost to giddiness, produced when first looking through the -4 D. The instinctive desire to see clearly and singly is so great, that the external recti contract, thereby balancing the increased contraction of the internal recti. Any increase of my accommodation above 4 D. when looking at $\frac{6}{6}$ causes the letters to become indistinct, the desire to maintain binocular vision, being greater than that for clear images. On placing the colored glass before one eye we diminish the retinal impression in that eye; the demand for binocular vision is lessened, the external recti ceases to act, and as a result of the increased action of the internal recti, squint results.

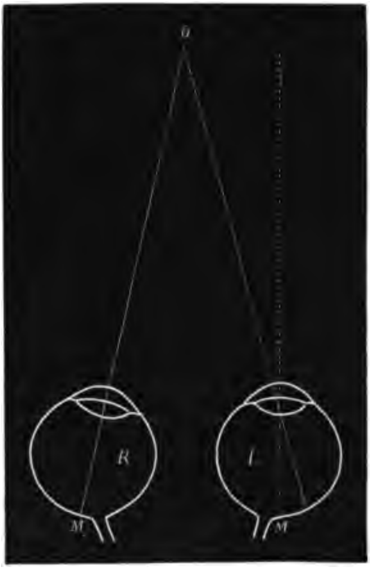
In the second experiment the retinal impression in one eye, even with so slight an amount of astigmatism, is reduced, so that with 2 D. of accommodation without convergence, the desire for clear images is greater than that for binocular vision, and diplopia the symptom of squint results.

A certain number of cases of convergent strabismus get well with advancing age; the probable explanation of this is, that as the accommodation diminishes, the time at length arrives, when the amount of accommodation at the patient's disposal, is not sufficient to produce clear images, he therefore relaxes his accommodation and with it, extreme convergence. This spontaneous cure is most likely to take place when the sight in both eyes is good.

Divergent strabismus exists when one eye only fixes the object looked at, the other deviating outwards (Fig.

88). It is usually dependent on myopia, but it may occur in any eyes, in which binocular vision does not

FIG. 88.



exist, as in some cases of high hypermetropia or astigmatism, or it may result from a too free division of the internal rectus muscle, in attempting to cure a case of convergent strabismus. It may also be paralytic.

The divergent is much less common than the convergent variety of strabismus.

In myopia the antero-posterior diameter of the eyeball is elongated, the range of movement is

diminished, and the extreme convergence which is necessary to enable the patient to see objects within his far point, tires out the internal recti muscles, giving rise to muscular asthenopia, to relieve which one of the internal recti gives way, and the eye deviates outwards.

Sometimes the deviation only takes place after the patient has been working some time and the eyes feel fatigued; in others it is only noticed when looking at objects beyond their far point. Soon, however, the squint becomes constant, and a divergent strabismus once established usually increases.

Treatment consists in prescribing proper glasses, and in some cases tenotomy.

In children when the squint is of small amount, and has existed only a short time as in the periodic form, the case can usually be cured by spectacles. The child is placed under atropine in the manner described when speaking of hypermetropia, and the amount of error of refraction found out by retinoscopy. If the case be convergent strabismus with hypermetropia, we order glasses that will correct the total error within 1 D or so (the nearer the full correction the better) with directions that they be worn constantly. It also frequently assists the cure to keep the child atropized for two or three weeks, wearing the glasses at the same time. Had the case been one of the less common forms of squint, divergent with myopia, we endeavour to give the patient as nearly as possible his full correction. When the vision in the two eyes is different, that in the squinting one being more or less

amblyopic, it is of service sometimes to exercise each eye separately for a certain fixed time daily.

When the squint is periodic it can always be cured by spectacles alone.

It will be seen that after the use of atropine the squint may be diminished, or in slight cases have disappeared, this is of course due to accommodation being rendered impossible.

Should the child be too young for spectacles (under three years), we must endeavour to prevent the increase of the squint and also prevent the deviating eye from becoming amblyopic, this can best be done by keeping the child atropized for a few weeks at a time, and occasionally tying up the eye which does not squint and so compelling the deviating eye to be used, thus preserving its visual acuteness; it has of course no effect on the deviation, the covered eye converging under the bandage: after the age of three spectacles may be prescribed.

When the spectacles have been worn two months without improvement or when the strabismus amounts to 50° or more, a tenotomy must be done. I think better results follow a limited operation on both muscles, than a free division of one.

Paralytic strabismus does not come within the province of this work.

See Case 22, page 215.

CHAPTER X

ASTHENOPIA

Asthenopia ('Α, priv; σθενος, strength; ὤψ, the eye) or weak sight is a term used to designate a group of symptoms, which indicates a condition of fatigue of the intra- or extra-ocular muscular systems.

Asthenopia frequently accompanies hypermetropia, myopia and astigmatism, and reference has often been made to it when speaking of these errors of refraction. We also meet with it in a certain number of cases where no ametropia exists.

Asthenopia shows itself by the inability to continue a steady and prolonged convergence, so that the patient complains that he is unable to read or write for any length of time, without the letters becoming indistinct and running together, pain over the eyes supervening. After a rest, he is able to resume his work, to be again interrupted after a shorter interval, and this is especially the case in the evening after a day's work. There is then moreover the disadvantage of an artificial light which always tends in these cases to increase the asthenopia. If the work be still persisted in, the pain around the eyes increases, there is photophobia, a sensation of dazzling and dimness, more or

less conjunctival congestion, with headache which sometimes passes on to nausea and sickness; the patient experiences a generally uncomfortable feeling about the eyes themselves, which become red and irritable. In some cases the symptoms have been so severe as to lead to the diagnosis of brain disease, and there is little doubt that frequently reflex nervous disorders are caused by asthenopia.

Asthenopia may be divided into—

1. Accommodative.
2. Muscular.
3. Reflex.

Accommodative Asthenopia is exceedingly common, and is produced by an inability to maintain the necessary accommodation, and may arise (*a*) from a weak condition of the ciliary muscle, (*b*) from excessive use, as in hypermetropia, (*c*) from unequal demand, as in astigmatism, (*d*) from unequal demand in the two eyes, as in anisometropia, (*e*) from diminished elasticity of the lens, as in presbyopia.

When Donders discovered the common occurrence of hypermetropia, he soon became aware of the intimate connection which existed between it and asthenopia; and was at first inclined to attribute every case to this cause. Where no manifest hypermetropia was present, he gave a solution of atropine to paralyse the accommodation, feeling confident that some latent hypermetropia would then display itself: such cases were usually completely cured by proper convex glasses. This accommodative asthenopia is due to the constant state of contraction

in which the ciliary muscle is kept, an emmetrope looking at distant objects, does so without any accommodation, the ciliary muscle being passive; but the hypermetrope has to use his ciliary muscle even for distant objects, and so much the more for reading or near work. The ciliary muscle practically gets no rest. A young and vigorous patient whose hypermetropia is not very high, may resist asthenopia for a long time, but as he gets old, or his health suffers from any cause, symptoms of this disorder are apt to appear. If the patient be a woman asthenopia is very liable to come on during lactation.

Treatment.—We order such glasses as are necessary to correct the refraction according to the rules given. In some cases where convex glasses do not produce the desired relief, prisms of 2° bases inwards combined with the spherical correction are of great use, or in slight cases we place the convex glasses somewhat near together so that the patient looks through the outer part of them (Fig. 90). This plan is frequently very useful in presbyopia. Here the asthenopia is due to a greater muscular effort being required to produce the necessary change in the shape of the less elastic lens, and perhaps also in part to the difficulty of maintaining an exact state of equilibrium between the internal and external recti muscles.

In hypermetropia there is a want of harmony between the accommodation and the convergence, the two functions having to be used in unequal degrees and when we correct his refraction with glasses, he will have to use these two functions equally, or at least in

different proportions to that to which he has been accustomed. Many people are able at once to accommodate themselves to this new state of affairs; but there are others in whom the force of habit is so strong that they cannot at once throw off the acquired habit of using the accommodation in excess of the convergence. You must not, therefore, be discouraged if occasionally your patient is not at once and completely relieved of his asthenopia, as soon as you have given him convex spectacles. A fortnight's trial should be made before we can decide that such spectacles will not relieve the patient of his asthenopia.

Asthenopia depends much upon the nervous system of the individual, in some a very slight amount of astigmatism will produce accommodative asthenopia; one hypermetrope will have no uncomfortable feelings, while another whose condition seems exactly similar, will suffer much, so that it is essential to attend to the patient's general health and nervous system.

Hypermetropes who squint are not usually troubled with asthenopia.

Muscular Asthenopia is most frequently due to myopia though it occasionally occurs in emmetropia or even hypermetropia, it is characterised by the inability to maintain prolonged convergence. The patient complains that the eyes become tired, especially during the evenings, when reading or writing cannot be continued for any length of time, then he has pain in and around the eyes, with headache; objects look dim and indistinct, and there is a tendency to see objects double; sometimes the patient experiences a sensation

13

as if one eye had turned outwards, which may really be the case, frequently the patient finds relief by closing one eye.

This muscular asthenopia is due to *insufficiency of the internal recti* muscles, whereby the muscular equilibrium is disturbed. The internal recti are weaker than their antagonists the external recti, so that they are obliged to keep up a vigorous action to prevent the eye from deviating outwards.

In myopia the disturbance of the two functions accommodation and convergence, may in some measure tend to the production of this form of asthenopia. Thus a patient with 4 D. of myopia has his punctum remotum at 25 cm., to see an object at that distance, he must converge to that point, maintaining at the same time a passive condition of his accommodation.

The two following tests for detecting this insufficiency of the internal recti are commonly employed.

The patient is directed to look at some small object (such as the point of a pencil) about 30 cm. off, with one eye, while the other is excluded with a ground glass disc, the pencil is now gradually approached, the covered eye being watched; at a certain point it will be seen to deviate slightly outwards, as soon as the eye is uncovered it makes a corresponding movement inwards to fix the object; on repeating the experiment with the other eye, exactly the same takes place, the reason of this is, that when one eye is covered the stimulus for binocular vision is lost, so that the eye which is excluded from vision is abandoned to the unbiassed action of its muscular system and deviates

outwards, returning to its normal position when again allowed to take its part in vision.

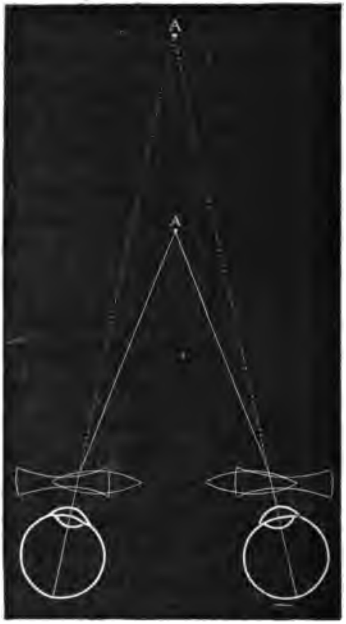
The second and more accurate test, is to place a prism of about 15°, with its base downwards, in a spectacle frame before one eye; by this means we cause a displacement of the eye upwards, and of course also vertical diplopia. The patient is now directed to look steadily at a card on which is drawn a line with a dot in its centre, placed at the patient's ordinary reading distance (Fig. 89). Naturally he will see two dots. If he see one line only with two dots on it, his muscles are assumed to be of the normal strength; if, however, two lines are seen with a dot on each, then insufficiency exists; and the strength of the prism which is necessary with its base inwards to produce fusion, is the measure of the insufficiency.

FIG. 89.

Treatment.—In cases of myopia we give such glasses as correct the refraction, and when worn constantly they frequently succeed in relieving the asthenopia, when such is not the case weak prisms bases inwards, by which we diminish the amount of convergence necessary, often give instant relief. It is sometimes useful to combine the prisms with concave glasses, or by separating the glasses somewhat widely, we produce the same result. Fig. 90 shows concave spectacles acting also as prisms by being slightly separated, and convex ones having

the same effect when placed so close together that the patient looks through the outer part of the lenses.

FIG. 90 (*Landolt*).



In addition to these cases of asthenopia occurring with hypermetropia, myopia, and astigmatism, which should be relieved by the glasses which are necessary to correct these errors, and restore the balance of their extra and intraocular muscular systems, everyone will occasionally meet with cases in which no ametropia exists, as proved by placing the patient under atropine and then testing his refraction. *Reflex*

asthenopia has been the name given to these cases, they are often exceedingly troublesome, and occur most frequently in young unmarried girls of an hysterical or nervous temperament. If it occur in men, such are usually feeble, hypochondriacal, and nervous. Frequently the only symptom present in addition to the patient's feelings of pain, tension, photophobia, heat, &c., is a certain amount of conjunctival trouble and increased secretion, with a feeling of itching and pricking. Sometimes with the ophthalmoscope, the retinal veins seem rather full, with or without a slight amount of haziness about the edges of the disc. This form of the disorder may be attributed to long hours of working, reading, or writing. I have met with several cases amongst those making gold lace, and no doubt the bright materials here worked with had something to do with the production of asthenopia. Complete abstinence from work does not always bring relief. It seems generally accepted by all authorities on this subject, that in such cases the nervous system is exceedingly sensitive and unstable. Frequently there is disturbance of the uterine organs; when leucorrhœa exists in young unmarried women with troublesome asthenopia, masturbation may be suspected. Irritation of the fifth nerve from carious teeth may also be a cause. The treatment of this reflex form of asthenopia is to endeavour to find out the cause and remove it, with rest for the eyes during certain fixed portions of the day.

CHAPTER XI

SPECTACLES

Having referred to the subject of spectacles, when considering the correction of the different forms of ametropia, I will now briefly recapitulate what was then said, even at the risk of being accused of unnecessary repetition.

Hypermetropia.—So long as $\frac{6}{6}$ can be read with each eye, no glass is necessary for distant vision; for reading &c., we give such glasses as correct the *manifest* and $\frac{1}{4}$ of the *latent* hypermetropia.

If distant vision be improved by convex glasses then such may be prescribed.

In hypermetropia complicated with strabismus we estimate the total hypermetropia under atropine, then give glasses that correct this within one dioptre; this correction to be worn constantly.

Myopia.—In cases of low degree we may prescribe folders for distance and allow the patient to read and write without glasses provided he keeps a long distance (30 cm.) from his book and suffers no inconvenience; the best results often ensue when the full correction is given, to be worn constantly both for near and distant objects.

Where the myopia is of high degree, the full correction may be satisfactory for distance, but uncomfortable or impossible for reading, owing to the accommodation being insufficient; such glasses also have the disadvantage of diminishing the size of objects, here we give two pairs of spectacles, one for distance and a weaker pair for reading.

Astigmatism.—Our object is to give as near as possible the full correction (found by atropising the patient), these glasses should be worn constantly.

Atropine is seldom necessary in patients over thirty years of age.

Convex glasses render parallel rays which pass through them convergent, they add therefore to the refraction of the dioptric system and are called *positive.*

Concave glasses render parallel rays divergent, they therefore diminish the refraction of the dioptric system and are called *negative.*

Convex glasses add to the quantity of light entering the eye, while concave glasses diminish it.

The size of the image is modified, thus positive glasses bring forward the centre of refraction and so increase the size of the image, while negative glasses carry this centre backwards and so diminish its size.

Glasses may be made of rock crystal or crown glass. There is a popular impression that those made of the former material (which are called pebbles) are the best, because they are harder and therefore less liable to be scratched. In reality, however, those made of crown glass are superior, because they refract more regularly besides being much cheaper.

The frames may be made of gold or steel. They should fit the face well. The bridge must suit the nose and be of such a height, that each eye looks exactly through the centre of its glass. When worn for myopia or hypermetropia they should not be further from the eye than 13 mm. For presbyopia the person may be allowed to suit his own convenience and comfort, 2½ cm. being an ordinary distance.

Single glasses may occasionally be allowed in low degrees of myopia for looking at distant objects. They have this disadvantage, however, viz. that sometimes one eye is used so entirely, that the sight in the other may deteriorate from want of sufficient use. Folders (pince-nez), may be used in similar cases to the above, and also to read or work with in presbyopia. Spectacles are as a rule to be preferred, since they are more accurately centred and fit better. For distant vision the glasses should be in the same straight line; for near vision they should slightly converge, so as to be exactly at right angles to the visual axes. In addition to concave, convex, and cylindrical glasses, others are sometimes used.

Stenopaic spectacles consist of an opaque screen with a small central aperture which may be of any shape according to the case, so that all the peripheral rays are cut off; only such as are in the optic axis being allowed to pass through. They can be combined with convex or concave glasses, and are often exceedingly useful in cases of leucoma, nebulæ, irregular astigmatism, myopia, &c., where the vision is much disturbed.

Prismatic spectacles may consist of prisms alone, or they may be in combination with concave or convex lenses. Their use is called for in certain cases of paralysis of muscles, to prevent diplopia; also in some cases of hypermetropia, when they are combined with convex glasses of the strength of 2° or 3°. With their help the patient is able to converge more, and therefore accommodate more, for a given point. Some myopes, who can read well without glasses, suffer from asthenopia, which can be relieved by prisms, bases inwards; because without them, they have to use their convergent power, their accommodation being at the same time passive.

Pantoscopic glasses, the upper half of these glasses have one focus, the lower half another. Thus a presbyopic person may also be myopic. The upper half of the glass would then be concave for distance, the lower half convex for near work. Painters sometimes find such glasses very useful.

Tinted glasses are sometimes required for diminishing too much light, in cases of irritation or inflammation of the retina, or of photophobia, from various causes, as myopia, &c. Where the aim is to relieve the retina without injuring the distinctness of vision, the light blue glasses are the best, as they cut off the orange rays; where the object is to act on the quantity and not the quality of the light, smoke colored glasses are to be preferred. Tinted glasses are always somewhat heating to the eyes, in proportion to the amount of rays they absorb. We sometimes combine them with convex or concave glasses.

There are also various forms of *protectors*; those hollowed out like a watch glass so as to fit closely, are to be preferred to those with wire sides called goggles, or those with sides of glass, which last have the disadvantage of being too heavy. Workmen wear different sorts of protectors to keep off dust, fragments of stone, &c., which may be made of glass, talc, or other material.

It is sometimes necessary to find out and record the strength of glasses that are being worn; this is easily done. If convex, we take a concave glass out of the trial box, hold it against the glass we are trying and look through them at a line, *e.g.* the bar of a window or any similar object, we move the glasses to and fro in front of the eye, if the line remain immovable the neutralization is complete, if it move in the same direction, the concave glass is too strong; if in the opposite direction, it is not strong enough.

Cases

Commence the examination in a systematic manner:

First, notice the general appearance of the patient, then the shape of the head and face. Next the eyes, as to whether they are large and prominent, or small and sunken-looking. Listen patiently to the sufferer's complaints, and having submitted to this ordeal, test the acuteness of vision of each eye separately, and afterwards together, writing down the result, remembering always to commence with convex glasses. Then

place the near type in the patient's hand, noting the punctum proximum and the punctum remotum. Next pass on to the ophthalmoscope, first applying the "retinoscopic test," then the "indirect examination," and finally the "direct method," first at a distance, and then close to the eye. If any ametropia exists, the advisability of paralysing the accommodation with atropine must be considered.

In order to illustrate this method of examination, I will give a few cases, in addition to those which will be found at the end of the chapter on Retinoscopy.

CASE 10. *Hypermetropia.*—E. M.—, a young woman, a bookbinder, æt. 17, suffering from tinea tarsi, complains that her eyes get very tired at night, so much so, in fact, that she is unable to read for any length of time. Her general appearance is healthy, and nothing special is noticed about her face, except that the eyes are small. The acuteness of vision for both eyes is normal. We try weak convex glasses 1 D. and she says that she sees somewhat clearer with them; we next try +2 D., then +3 D., and find that with these last the patient is unable to read $\frac{6}{6}$. +2 D. for each eye, is the strongest convex glass with which $\frac{6}{6}$ can be read, and is therefore the measure of her Hm. We record it thus—

$$\text{R. V. } \tfrac{6}{6} \text{ Hm. 2 D.} = \tfrac{6}{6}$$
$$\text{L. V. } \tfrac{6}{6} \text{ Hm. 2 D.} = \tfrac{6}{6}$$

We next place the patient in the dark room, directing her to look at some distant object or at a black wall, so as to relax as much as possible her

accommodation, and apply the retinoscopic test. The shadow we perceive moves slowly against the mirror, we put +2 D. in a spectacle frame, in front of the eye. The shadow is more distinct, and moves more quickly. We try stronger glasses and then find that +3·5 D. is the highest with which we still get a reverse shadow. Both eyes are alike.

Next examine with the ophthalmoscope. By the indirect method the disc becomes smaller on withdrawing the objective from the eye. With the mirror alone at a distance, we see an image of the disc which moves with the observer's head, showing it therefore to be an erect image. On approaching the eye the disc is not seen well, unless we put in force our own accommodation; with our accommodation suspended, we turn the wheel of the ophthalmoscope so as to bring forward convex glasses, the clearness of the fundus is improved. +3 D. is the strongest convex glass with which the details can be distinctly and clearly seen by myself.

We might be satisfied with this result, assuming 3·5 D. to be the amount of total hypermetropia; but in young people it is much more satisfactory to be able to record once and for all the total hypermetropia beyond doubt. I therefore order the patient, Guttæ Atrop., grs. iv to ℥j, one or two drops to be placed in both eyes three times a day for four days, warning her that she will be unable to see so well and that the pupils will be dilated during their use. We also recommend a shade to be worn to protect the eyes from the light.

On her return she reads only $\frac{6}{60}$ with each eye, and she now requires $+5$ D. to enable her to read $\frac{6}{6}$. We also find with retinoscopy that $+5$ D. is the strongest glass with which we get an opposite shadow.

Our patient, therefore, has a total hypermetropia of 5 D., two of which were manifest and three latent. For work and reading we order her spectactes $+3$ D. At present she will not require them for distance. About thirty she will probably require her glasses increased to $+4$ D., and may then begin to wear them constantly; about forty she may be able to bear her full correction.

We must remember that when atropine has been used it is necessary to take off 1 D. from the measurements thus found, for the tone of the ciliary muscle.

Case 11. *Myopia.*—A young man, æt. 20, next presents himself. He has a long intellectual face with prominent nose; the palpebral apertures are wide; and on directing him to look inwards as much as possible, the eyeballs seem elongated in an antero-posterior diameter.

His eyes, he says, are excellent, but he is unable to recognise people as well as formerly. We test the acuteness of vision, and find that he reads $\frac{6}{36}$ with each eye. Convex glasses make even that line indistinct. Our patient is probably myopic. We place in his hand the near type, and he reads No. 1, at once and easily. The farthest point at which he can read it, is 25 cm. ($\frac{100}{25}=4$ D.) -4 D. should be the measure of his myopia. We try -4 D. directing him again to look at the distant type. He reads with each

eye $\frac{6}{6}$; we reduce the glass to find the *weakest* with which he reads the same, and with $-3{\cdot}5$ D. he reads it, though hardly so well; with -3 D. he reads only $\frac{6}{9}$; $-3{\cdot}5$ D. is therefore the measure of his myopia, and we record it thus—

$$\text{R. V. } \tfrac{6}{36} - 3{\cdot}5 \text{ D.} = \tfrac{6}{6}.$$
$$\text{L. V. } \tfrac{6}{36} - 3{\cdot}5 \text{ D.} = \tfrac{6}{6}.$$

If we employ retinoscopy $-3{\cdot}5$ D. is the weakest concave glass with which a reverse shadow is produced.

We next subject the eye to the indirect ophthalmoscopic examination. The disc becomes larger on placing the objective near the eye and gradually withdrawing it, and in addition we see also a slight myopic crescent on the apparent inner side of the disc. From this case, disc No. 1 was drawn (page 131).

With the direct ophthalmoscope at a distance from the eye, the disc cannot be well seen, because in our case the aërial image will be formed about 25 cm. in front of the patient's eye. To enable us to see this aërial image it is necessary we should be some 30 cm. away from it; so that we should require to be $25+30$ $=55$ cm. from the observed eye, and at that distance the illumination will be very weak. With the mirror close to the patient's eye, the details appear blurred until we put on a concave glass, by turning the wheel of our refracting ophthalmoscope. The weakest concave glass with which we are able to see the details of the fundus clearly is the measure of the myopia. Thus

we have four distinct plans of measuring our case of myopia :

1st. The farthest distance at which the near type is read 25 cm. ($\frac{100}{25}$=4 D.).

2nd. The *weakest* concave glass which gives the greatest acuteness of vision.

3rd. The *weakest* concave glass with which we get a retinoscopic shadow moving in the opposite direction to the movement of the mirror.

4th. The *weakest* concave glass with which the details of the fundus can be distinctly seen by the direct ophthalmoscopic examination *close to* the eye.

Should any of these results vary much, we should suspect that the myopia is increased by spasm of the accommodation, and we atropize the patient in the manner before described, and at the end of four days go over the ground again, remembering that when atropine has been used, it is necessary to add on about −·5 D. to the glass found, because the ciliary muscle is probably never so completely relaxed as when it is under the influence of atropine. Therefore we add −·5 D. for what is called the tone of the ciliary muscle.

Having found then that our patient's myopia amounts to −3·5 D. we give spectacles of that focus for constant use. In addition to ordering spectacles we give him also some very important general directions; he must always hold his book or work 35 cm. away, bring the work to his eyes, and not his eyes to the work, his writing should be done at a sloping desk, he should sit with his back to the window so that the

light comes over his left shoulder on to his work, and do as little near work as possible by artificial light.

CASE 12. *Hypermetropia and Presbyopia.*—A gentleman, æt. 56, comes with the complaint that he cannot see to read as comfortably as formerly, though he sees distant objects well. We try his acuteness of vision, and find that he reads $\frac{6}{9}$ badly. With +1 D. he sees much better, reading some of the letters of $\frac{6}{6}$. We then try 1·5 D. and these he rejects. Hence we conclude that he has Hm. 1 D. We know from his age that he will also be presbyopic 3 D. and we add on to this + 1 D. for hypermetropia, directing him to read the newspaper with +4 D. for half an hour. He thinks these rather strong for him, as they make his eyes ache. With +3·5 D. he feels quite comfortable, and we therefore give him +3·5 D., telling him that he will require them changed for slightly stronger ones in about five years.

CASE 13. *Paralysis of the Accommodation.*—Kate L—, æt. 12, has been very ill from diphtheria, but is now much better. She complains that she is unable to read or work, though able to see distant objects well. The pupils are very large and act badly to light. Hence we suspect paralysis of the accommodation. We test her acuteness of vision, and she sees $\frac{6}{6}$ with each eye. We try convex glasses ·5 D., and she still reads $\frac{6}{6}$, but 1 D. she rejects. Our diagnosis is therefore confirmed. We next find the weakest glass with which she is able to read, *weakest* because we are anxious to encourage the ciliary muscle to act, since

by replacing it entirely we should prolong the patient's recovery.

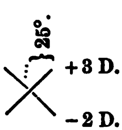
The glasses must be changed for weaker ones as the ciliary muscle recovers tone.

We saw that she had a slight amount of hypermetropia and also that there was some accommodation left, enough at least to correct this, otherwise she could not have read $\frac{6}{6}$ without $+\cdot5$. A tonic containing iron and strychnine was also prescribed.

CASE 14. *Anisometropia.*—A young woman, æt. 20, has never seen well, either at a distance or near at hand, has tried spectacles of all sorts, but never been able to find any that suited her. The eyes look somewhat irritable, but there is nothing conspicuous about their size or shape. There is some want of symmetry about the face, the nose being deviated from the median line slightly to the left.

We first try the acuteness of vision of the right eye. She reads $\frac{6}{12}$ and with $+1$ D. vision is somewhat improved; with $+1\cdot5$ D. it is made worse. Still armed with $+1$ D. we direct the patient to look at the fan of radiating lines (Fig. 77). She sees plainly the horizontal lines, whilst all the others are more or less indistinct, the vertical line most so; still looking at the horizontal line, we alternately hold in front of $+1$ D. which is before the eye under examination, $+\cdot25$ D. which makes it worse, then $-\cdot25$ D. which she says at once makes it perfectly clear and distinct. We, therefore, put down $+\cdot75$ as the correction for the vertical meridian, and pass on to the horizontal. Our patient is directed to look steadily at the vertical line. We try

convex glasses which improve it, + 3 D. making it quite clear; a stronger glass than this renders it slightly indistinct. It is evident, therefore, that her horizontal meridian is hypermetropic + 3 D. We put up the correction found, + ·75 D. sp., + 2·25 D. cylinder axis vertical, and direct her again to look at the distant type. $\frac{6}{6}$ is read though with some difficulty. This result is not, however, reliable, and we proceed to confirm it by retinoscopy, obtaining + 3 D. for the vertical, and + 5 D. for the horizontal meridians. On trying this correction, however, the vision is not so good. We now test the acuteness of vision in the left eye. She sees $\frac{6}{36}$, and neither convex nor concave glasses improve it. On looking at the fan of radiating lines all seems indistinct, and having thus far no data to go upon, we, instead of wasting time, at once pass on to retinoscopy. We get oblique shadows, the horizontal moving with the mirror and the vertical against it; here then is a case of mixed astigmatism. We find out that − 2 D. is the weakest concave glass, with which we get a reverse shadow horizontally, and + 3 D. the strongest convex with which an opposite shadow is still obtained in the vertical meridian, the degree of obliquity being about 25°. This result we note down as—

L. 

We, therefore, place in a spectacle frame + 3 D. spherical combined with − 5 D. cylinder, axis deviating

outwards from the vertical 25°. With this correction the patient at once reads $\frac{6}{12}$. We are not to be satisfied with this result, but give the patient a solution of atropine grs. 4 to ℥j with directions to come again in four days. At the end of that time she returns, and we find with retinoscopy—

R. +2·5. +4·5 D. L. +3·5 D. −2 D.

The right eye with this correction reads $\frac{6}{6}$ and the left also $\frac{6}{6}$. This result is very satisfactory. We now allow the patient to recover from atropine, and at the end of a week confirm the result before ordering spectacles. Then we found for the right eye the best vision with +1·5 sp. ⊂ +2 D. cy. axis vertical ($\frac{6}{6}$,); the left +3 D. spherical ⊂ −5 D. cylin. axis 20° from the vertical gave $\frac{6}{6}$. These spectacles were therefore ordered and the patient directed to wear them constantly.

Case 15. *Anisometropia.*—Jane W—, æt. 30, presents herself complaining that the sight in her left eye has been gradually getting dim for some months. She is a small, healthy-looking woman, with nothing characteristic in her appearance. We test the acuteness of vision—

Right $\frac{6}{6}$ Hm. 1 D. = $\frac{6}{6}$.

Left $\frac{6}{18}$, not improved with spherical glasses.

We try retinoscopy, but the pupils are so small that the result is not very satisfactory. We are, however, able to make out in the left eye a reverse shadow in the horizontal meridian, which +2 D. overcorrects,

+1·5 D. being the highest glass with which we get an opposite shadow. The vertical meridian appears emmetropic. There is, therefore, no doubt that the defective vision in this eye is due to astigmatism. The patient complains that the examination has made her eyes ache, so we do not proceed further, but order a solution of hydrobromate of homatropine (2 grs. to the ℥j) to be used every two hours, and direct her to come again on the following day. Then the result with retinoscopy is—

R. + 1·5 D.

+ ·5 D.
L.—|— + 2 D.

We try this at the test type.

$$\text{R. } \tfrac{6}{9} + 1\cdot5 \text{ D.} = \tfrac{6}{6}.$$

$$\text{L. } \tfrac{6}{36} + \frac{\cdot5 \text{ D. sp.}}{1\cdot5 \text{ D. cy. axis vert.}} = \tfrac{6}{6}.$$

The effect of the homatropine soon passes off on discontinuing its use, and in a couple of days we confirm the result.

Finally we then find—

$$\text{R. } \tfrac{6}{6} + 1 \text{ D.} = \tfrac{6}{5}.$$

$$\text{L. } \tfrac{6}{24} + 1\cdot5 \text{ cy. axis vert.} = \tfrac{6}{6}.$$

These spectacles are to be worn constantly.

Case 16. *Presbyopia.*—John G—, æt. 50, has always enjoyed good sight, he still sees distant objects well, but finds some difficulty in reading especially during the evenings.

R.V. $\tfrac{6}{6}$, no Hm.
L.V. $\tfrac{6}{6}$, no Hm.

We try him with $+2$ D. for reading and with these he sees perfectly; this therefore is a simple case of presbyopia, requiring a pair of folders $+2$ D. for reading, writing, &c.

CASE 17. *Hypermetropia and Presbyopia.*—Mr. K—, æt. 60, sees badly both near and distant objects, he wears $+4$ D. for reading but they are not comfortable.

R.V. $\frac{6}{36}$, Hm. 3 D.$=\frac{6}{6}$.
L.V. $\frac{6}{36}$, Hm. 3 D.$=\frac{6}{6}$.

He therefore requires $+3$ D. for distance, and to find the glass he will require for reading, it is necessary to add on to this distance glass, the glass he would require for presbyopia if he were an emmetrope, viz. $+4$ D. We therefore try him with $+7$ D., but these he thinks rather strong, they make his eyes ache, we next try $+6{\cdot}5$ D. and with these he sees comfortably.

This patient then requires two pairs of spectacles—

$+3$ D. for distance.
$+6{\cdot}5$ D. for reading, &c.

CASE 18. *Myopia and Presbyopia.*—Mrs. C—, æt. 55, complains that her eyes become tired at night, she has tried several pairs of spectacles, but without finding any that exactly suit her.

R.V. $\frac{6}{36}-2$ D.$=\frac{6}{6}$.
L.V. $\frac{6}{36}-2$ D$=\frac{6}{6}$.

Our patient requires therefore this correction for distance, but she also wants glasses for reading and near work; an emmetrope of 55 requires presbyopic glasses $+3$ D., she is however a myope of 2 D., so we

have to deduct this from the presbyopic glass (3 D. -2 D. $=1$ D.) and try the $+1$ D. for reading. With these she is able to read the smallest type comfortably, we therefore prescribe 2 pairs of spectacles—

-2 D. for distance.
$+1$ D. for reading.

CASE 19. *Myopia.*—Annie C—, æt. 9, was brought because she was unable to see the black board at school.

R.V. $\frac{6}{24} - 3{\cdot}5$ D. $= \frac{6}{9}$.
L.V. $\frac{6}{24} - 2{\cdot}5$ D. $= \frac{6}{9}$.

After using atropine—

R.V. $\frac{6}{36} - 3$ D. $= \frac{6}{9}$.
L.V. $\frac{6}{24} - 2$ D. $= \frac{6}{9}$.

Ordered spectacles for distance R. -3 D., L. -2 D., with directions to present herself again in six months, when, should the myopia have increased, or if the child complain of asthenopia, it may be necessary to prescribe spectacles for constant use.

CASE 20. *Simple Myopic Astigmatism.*—Thomas J—, æt. 20, sees rather badly both near and distant objects.

R.V. $\frac{6}{12}$, not improved with glasses; with pin-hole $= \frac{6}{9}$.
L.V. $\frac{6}{12}$, not improved with glasses; with pin-hole $= \frac{6}{9}$.

After atropine had been used for four days retinoscopy gave—

	+1 D.		+1 D.
R.	Em.	L.	Em.

R. $+1$ D. cy. axis horiz. $= \frac{6}{6}$.
L. $+1$ D. cy. axis horiz. $= \frac{6}{6}$.

After the atropine had passed off—

R. -1 D. cy. axis vert. $=\frac{6}{6}$.
L -1 D. cy. axis vert. $=\frac{6}{6}$.

This correction was given for constant use.

Case 21. *Compound Myopic Astigmatism.*—Miss N—, æt. 13, has seemed short-sighted for the last year or two. Mother and father both have good sight.

R.V. $\frac{3}{60}-9$ D. $=\frac{6}{24}$.
L.V. $\frac{3}{60}-9$ D. $=\frac{6}{24}$.

The pupils are large, so that retinoscopy can be easily carried out.

$$\text{R.}\!\!-\!\!\Big|\begin{array}{l}-10\text{ D.}\\ \text{---}-6\text{ D.}\end{array}\qquad\qquad \text{L.}\!\!-\!\!\Big|\begin{array}{l}-10\text{ D.}\\ \text{---}-7\text{ D.}\end{array}$$

$$\text{R.V.}\frac{-6\text{ D. sp.}}{-4\text{ D. cy. axis horiz.}}=\frac{6}{18}\text{ and 2 letters of }\frac{6}{12}.$$

$$\text{L.V.}\frac{-7\text{ D. sp.}}{-3\text{ D. cy. axis horiz.}}=\frac{6}{12}.$$

On examination of the eyes with the ophthalmoscope the choroid is found to be exceedingly thin, there is a large crescent in both eyes and in the right three or four patches of choroiditis with one hæmorrhage near the macula.

The patient was ordered the full correction for distance, and advised to do no reading, writing or near work for six months, then to return for inspection, she was also recommended to spend as much of her time as possible in the open air, and a mixture containing syrup of the iodide of iron was prescribed.

Case 22. *Concomitant Squint.*—George W—, æt. 5, has squinted inwards for the last three months. On

covering the non-squinting eye and directing the little boy to look at the finger held a short distance from him, the deviating eye immediately righted itself and fixed the finger, the covered eye at the same time turning in. We prescribe a solution of atropine to be applied to both eyes and at the end of a week the patient is brought back to us, the squint is now much less apparent, and with retinoscopy we find 3·5 D. of hypermetropia in each eye. The direct examination gives the same result. We order our patient spectacles + 2·5 D. to be worn constantly.

CASE 23. *Aphakia.*—Thomas B—, æt. 50, gamekeeper. Had the right lens removed for cataract nine months ago, and last week the opaque capsule remaining was needled.

R. V. c̄ + 11 D. = $\frac{6}{9}$ and with + 14 D. No. 1 of the near type was read with comfort, the patient was therefore ordered the following spectacles—

+ 11 D. for distance.
+ 14 D. for near work.

These were arranged in a reversible frame, so that either glass could be brought in front of the right eye as occasion required.

APPENDIX

In the metrical system the unit of length is a metre, equal to 100 centimetres, 1000 millimetres or 40 English inches, so that 1 inch is equal to $2\frac{1}{2}$ centimetres, a lens of 1-metre focus is called a dioptre, a lens of $\frac{1}{2}$ a metre (50 cm.) is 2 D., $\frac{1}{10}$ of a metre (10 cm.) 10 D., &c.

In the old system the lenses were numbered according to their focal length in inches, a lens of 1-inch focus being the unit; a lens of 2-inch focus was expressed by the fraction $\frac{1}{2}$, one of 10-inch focus $\frac{1}{10}$, and so on. If we wish to convert a dioptric measurement, into the corresponding inch measurement of the old system, we have only to remember that the unit 1 metre $=40$ English inches, so that a glass of 1 D.$=\frac{1}{40}$ in the old system, 2 D.$=\frac{2}{40}=\frac{1}{20}$, 5 D.$=\frac{5}{40}=\frac{1}{8}$, and so on.

The table on the next page gives approximately the equivalent of each dioptre or part of a dioptre in English and French inches and in centimetres.

Dioptres.	English inches.	French inches.	Centimetres.
·25	160	146	400
·50	80	73	200
·75	52	50	130
1·	40	36	100
1·25	31	29	77
1·50	26	24	65
1·75	22	21	55
2·	20	18	50
2·25	17	16	43
2·50	16	15	40
2·75	14	13	35
3·	13	12	33
3·50	11	10	27
4·	10	9	25
4·50	9	8	22
5·	8	7	20
5·50	7	6½	17
6·	6½	6	16
7·	6	5	15
8·	5	4½	12½
9·	4½	4	11
10·	4	3½	10
11·	3½	3¼	9
12·	3¼	3	8
13·	3	2¾	7½
14·	2¾	2½	7
15·	2½	2¼	6½
16·	2¼	2⅛	6
18·	2⅛	2	5½
20·	2	1¾	5

Authors to whom the writer is indebted:

DONDERS. Accommodation and Refraction of the Eye.

GLAZEBROOK. Physical optics.

GIRAUD-TEULON. La Vision et ses anomalies. The Function of Vision. (Translated by Lloyd Owen.)

JACKSON. On Retinoscopy.

LANDOLT. Examination of the Eyes.

DE WECKER et LANDOLT. Traité complet d'ophthalmologie.

SOELBERG WELLS. A Treatise on the Diseases of the Eye.

NETTLESHIP. Diseases of the Eye.

MACNAMARA. Manual of Diseases of the Eye.

MORTON. Refraction of the Eye.

CHARNLEY. On Keratoscopy.

TEST TYPES.

---

33 cm.* *No.* 1.

A dull grey sky, hills and trees, and meadow banks and boats deepening down into undistinguishable masses of neutral tint: the river like another grey sky—as smooth and unruffled, save when boats are plashing about. Down by the lock yonder a bonfire is shooting up a ruddy glare into the dusk gathering about the wooded hill in the background, and white bell tents are dotted here and there in the valley, cold and spectral, or all aglow with lights within. Up under the willows, weird-looking figures are rigging up awnings over boats, in which they are going to sleep for the night, and in many of which brilliant lights are bringing brawny

50 cm. *No.* 2.

oarsmen into bold relief against the black shadows in the trees behind. Just above the bridge acres of small boats lie slumbering along the towing-path, the water softly plashing a lullaby beneath them. Lower down, far as the eye can reach, lights are twinkling and flashing in countless multitudes, and sounds of music, softened by distance, come tinkling over the gleaming river. It is ten o'clock and past, and the great throng of holiday-makers has for the most part dispersed apparently; but with the fading out of daylight there has gradually

60 cm. *No.* 3.

beamed out upon the river a scene which, if it were to be enjoyed only in Venice, and once every five years, would draw spectators from all the ends of the earth. One side of the river is seemingly all but deserted, and lies hidden in darkness as profound as darkness can be in the height of summer, with nothing but a thin curtain of clouds spread out beneath a nearly full moon. But the side of the river opposite to the towing-

90 cm. *No.* 4.

path is one long line of sparkling light, while over the dark glistening river seemingly hundreds of boats are paddling about, many of them decked out with Chinese lanterns and riding lights at their tiny mast-heads. The brilliancy and vivacity of the scene, combined with its quietude and placidity is difficult to describe, without appearing to

---

* The number indicates the distance at which the type should be seen by a normal eye.

1 m. *No.* 5.

indulge in somewhat extravagant language. Henley Regatta seems to be year by year growing in popular favour—unfortunately, no doubt, many will think—and the line of house-boats which a few seasons ago extended no great distance down below the winning flag and the

1·5 m. *No.* 6.

grand stand may be said now to reach right down the course of a mile and a quarter or so. By day these house-boats are exceedingly gay and pleasant-looking, with their coloured awnings, their profusion of brilliant bunting,

1·8 m. *No.* 7.

their extemporised flower gardens, the brightly-coloured boating costumes of the men, and the gay dresses of the ladies. Until quite a recent period the display by day was thought

2 m. *No.* 8.

to be sufficient, but one or two boats began the fashion of illuminating after dark, and it has now become quite

3 m. *No.* 9.

correct to light up.
Small boats followed

5 m. *No.* 10.

in the wake,
the brilliant

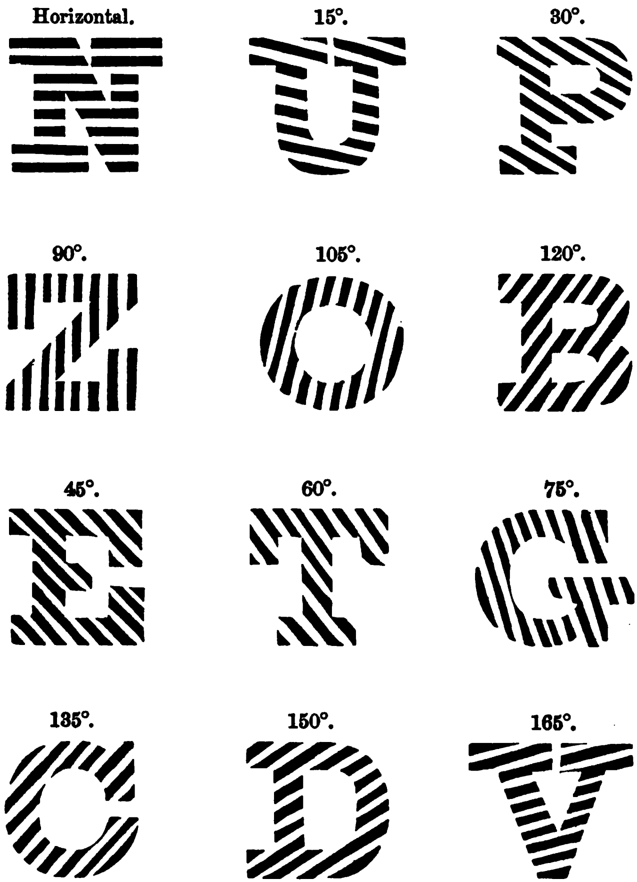
6 m. *No.* 11.

Z E D A O P

12 m. *No.* 12.

B A E

PRAY'S TEST TYPES FOR ASTIGMATISM.



INDEX

PRINTED BY J. E. ADLARD, BARTHOLOMEW CLOSE.

LONDON, *September*, 1885.

J. & A. CHURCHILL'S

MEDICAL CLASS BOOKS.

ANATOMY.

BRAUNE.—An Atlas of Topographical Anatomy, after Plane Sections of Frozen Bodies. By WILHELM BRAUNE, Professor of Anatomy in the University of Leipzig. Translated by EDWARD BELLAMY, F.R.C.S., and Member of the Board of Examiners; Surgeon to Charing Cross Hospital, and Lecturer on Anatomy in its School. With 34 Photo-lithographic Plates and 46 Woodcuts. Large Imp. 8vo, 40s.

FLOWER.—Diagrams of the Nerves of the Human Body, exhibiting their Origin, Divisions, and Connexions, with their Distribution to the various Regions of the Cutaneous Surface, and to all the Muscles. By WILLIAM H. FLOWER, F.R.C.S., F.R.S. Third Edition, containing 6 Plates. Royal 4to, 12s.

GODLEE.—An Atlas of Human Anatomy: illustrating most of the ordinary Dissections and many not usually practised by the Student. By RICKMAN J. GODLEE, M.S., F.R.C S., Assistant-Surgeon to University College Hospital, and Senior Demonstrator of Anatomy in University College. With 48 Imp. 4to Coloured Plates, containing 112 Figures, and a Volume of Explanatory Text, with many Engravings. 8vo, £4 14s. 6d.

HEATH.—Practical Anatomy: a Manual of Dissections. By CHRISTOPHER HEATH, F.R.C.S., Holme Professor of Clinical Surgery in University College and Surgeon to the Hospital. Sixth Edition, revised by RICKMAN J. GODLEE, M.S. Lond., F.R.C.S., Demonstrator of Anatomy in University College, and Assistant Surgeon to the Hospital. With 24 Coloured Plates and 274 Engravings. Crown 8vo, 15s.

ANATOMY—*continued.*

HOLDEN.—A Manual of the Dissection of the Human Body. By LUTHER HOLDEN, F.R.C.S., Consulting-Surgeon to St. Bartholomew's Hospital. Fifth Edition, by JOHN LANGTON, F.R.C.S., Surgeon to, and Lecturer on Anatomy at, St. Bartholomew's Hospital. With 208 Engravings. 8vo, 20s.

By the same Author.

Human Osteology: comprising a Description of the Bones, with Delineations of the Attachments of the Muscles, the General and Microscopical Structure of Bone and its Development. Sixth Edition, revised by the Author and JAMES SHUTER, F.R.C.S., late Assistant-Surgeon to St. Bartholomew's Hospital. With 61 Lithographic Plates and 89 Engravings. Royal 8vo, 16s.

ALSO,

Landmarks, Medical and Surgical. Fourth Edition. [*In the press.*

MORRIS.—The Anatomy of the Joints of Man. By HENRY MORRIS, M.A., F.R.C.S., Surgeon to, and Lecturer on Anatomy and Practical Surgery at, the Middlesex Hospital. With 44 Plates (19 Coloured) and Engravings. 8vo, 16s.

The Anatomical Remembrancer; or, Complete Pocket Anatomist. Eighth Edition. 32mo, 3s. 6d.

WAGSTAFFE.—The Student's Guide to Human Osteology. By WM. WARWICK WAGSTAFFE, F.R.C.S., late Assistant-Surgeon to, and Lecturer on Anatomy at, St. Thomas's Hospital. With 23 Plates and 66 Engravings. Fcap. 8vo, 10s. 6d.

WILSON — BUCHANAN — CLARK. — Wilson's Anatomist's Vade-Mecum: a System of Human Anatomy. Tenth Edition, by GEORGE BUCHANAN, Professor of Clinical Surgery in the University of Glasgow, and HENRY E. CLARK, M.R.C.S., Lecturer on Anatomy in the Glasgow Royal Infirmary School of Medicine. With 450 Engravings, including 26 Coloured Plates. Crown 8vo, 18s.

BOTANY.

BENTLEY.—**A Manual of Botany.** By Robert Bentley, F.L.S., M.R.C.S., Professor of Botany in King's College and to the Pharmaceutical Society. With 1185 Engravings. Fourth Edition. Crown 8vo, 15s.

By the same Author.

The Student's Guide to Structural, Morphological, and Physiological Botany. With 660 Engravings. Fcap. 8vo, 7s. 6d.

ALSO,

The Student's Guide to Systematic Botany, including the Classification of Plants and Descriptive Botany. With 357 Engravings. Fcap. 8vo, 3s. 6d.

BENTLEY AND TRIMEN.—**Medicinal Plants:** being descriptions, with original Figures, of the Principal Plants employed in Medicine, and an account of their Properties and Uses. By Robert Bentley, F.L.S., and Henry Trimen, M.B., F.L.S. In 4 Vols., large 8vo, with 306 Coloured Plates, bound in half morocco. gilt edges, £11 11s.

CHEMISTRY.

BERNAYS.—**Notes for Students in Chemistry;** being a Syllabus of Chemistry compiled mainly from the Manuals of Fownes-Watts, Miller, Wurz, and Schorlemmer. By Albert J. Bernays, Ph.D., Professor of Chemistry at St. Thomas's Hospital. Sixth Edition. Fcap. 8vo, 3s. 6d.

BLOXAM.—**Chemistry, Inorganic and Organic;** with Experiments. By Charles L. Bloxam, Professor of Chemistry in King's College. Fifth Edition. With 292 Engravings. 8vo, 16s.

By the same Author.

Laboratory Teaching; or, Progressive Exercises in Practical Chemistry. Fourth Edition. With 83 Engravings. Crown 8vo, 5s. 6d.

CHEMISTRY—*continued.*

BOWMAN AND BLOXAM.—Practical Chemistry, including Analysis. By JOHN E. BOWMAN, and CHARLES L. BLOXAM, Professor of Chemistry in King's College. Eighth Edition. With 90 Engravings. Fcap. 8vo, 5s. 6d.

BROWN. — Practical Chemistry: Analytical Tables and Exercises for Students. By J. CAMPBELL BROWN, D.Sc. Lond., Professor of Chemistry in University College, Liverpool. Second Edition. 8vo, 2s. 6d.

CLOWES.—Practical Chemistry and Qualitative Inorganic Analysis. Adapted for use in the Laboratories of Schools and Colleges. By FRANK CLOWES, D.Sc. Lond., Professor of Chemistry in University College, Nottingham. Fourth Edition. With Engravings. Post 8vo, 7s. 6d.

FOWNES.—Manual of Chemistry.—*See WATTS.*

FRANKLAND AND JAPP.—Inorganic Chemistry. By EDWARD FRANKLAND, Ph.D., D.C.L., F.R.S., and F. R. JAPP, M.A. Ph.D., F.I.C. With 2 Lithographic Plates and numerous Wood Engravings. 8vo, 24s.

TIDY.—A Handbook of Modern Chemistry, Inorganic and Organic. By C. MEYMOTT TIDY, M.B., Professor of Chemistry and Medical Jurisprudence at the London Hospital, 8vo, 16s.

VACHER.—A Primer of Chemistry, including Analysis. By ARTHUR VACHER. 18mo, 1s.

VALENTIN.—Chemical Tables for the Lecture-room and Laboratory. By WILLIAM G. VALENTIN, F.C.S. In Five large Sheets, 5s. 6d.

VALENTIN AND HODGKINSON.—A Course of Qualitative Chemical Analysis. By W. G. VALENTIN, F.C.S. Sixth Edition by W. R. HODGKINSON, Ph.D. (Wurzburg), Senior Demonstrator of Practical Chemistry in the Science Schools, South Kensington, and H. M. CHAPMAN, Assistant Demonstrator. With Engravings and Map of Spectra. 8vo, 8s. 6d.

The Tables for the Qualitative Analysis of Simple and Compound Substances, with Map of Spectra, printed separately on indestructible paper. 8vo, 2s. 6d.

CHEMISTRY—*continued.*

WATTS.—**Physical and Inorganic Chemistry.** By HENRY WATTS, B.A., F.R.S. (being Vol. I. of the Thirteenth Edition of Fownes' Manual of Chemistry). With 150 Wood Engravings, and Coloured Plate of Spectra. Crown 8vo, 9s.

By the same Author.

Chemistry of Carbon - Compounds, or Organic Chemistry (being Vol. II. of the Twelfth Edition of Fownes' Manual of Chemistry). With Engravings. Crown 8vo, 10s.

CHILDREN, DISEASES OF.

DAY.—**A Manual of the Diseases of Children.** By WILLIAM H. DAY, M.D., Physician to the Samaritan Hospital for Women and Children. Second Edition. Crown 8vo, 12s. 6d.

ELLIS.—**A Practical Manual of the Diseases** of Children. By EDWARD ELLIS, M.D., late Senior Physician to the Victoria Hospital for Sick Children. With a Formulary. Fourth Edition. Crown 8vo, 10s.

GOODHART.—**The Student's Guide to Diseases** of Children By JAMES F. GOODHART, M.D., F.R.C.P., Assistant Physician to Guy's Hospital; Physician to the Evelina Hospital for Sick Children. Fcap. 8vo, 10s. 6d.

SMITH.—**On the Wasting Diseases of Infants** and Children. By EUSTACE SMITH, M.D., F.R.C.P., Physician to H.M. the King of the Belgians, and to the East London Hospital for Children. Fourth Edition. Post 8vo, 8s. 6d.

By the same Author.

A Practical Treatise on Disease in Chil-dren. 8vo, 22s.

STEINER.—**Compendium of Children's Dis-**eases; a Handbook for Practitioners and Students. By JOHANN STEINER, M.D. Translated by LAWSON TAIT, F.R.C.S., Surgeon to th Birmingham Hospital for Women, &c. 8vo, 12s. 6d.

DENTISTRY.

GORGAS.—**Dental Medicine: a Manual of** Dental Materia Medica and Therapeutics, for Practitioners and Students. By FERDINAND J. S. GORGAS, A.M., M.D., D.D.S., Professor of Dentistry in the University of Maryland; Editor of "Harris's Principles and Practice of Dentistry," &c. Royal 8vo, 14s.

HARRIS.—**The Principles and Practice of** Dentistry; including Anatomy, Physiology, Pathology, Therapeutics, Dental Surgery, and Mechanism. By CHAPIN A. HARRIS, M.D., D.D.S. Eleventh Edition, revised and edited by FERDINAND J. S. GORGAS, A.M., M.D., D.D.S. With 750 Illustrations. 8vo, 31s. 6d.

SEWILL.—**The Student's Guide to Dental** Anatomy and Surgery. By HENRY E. SEWILL, M.R.C.S., L.D.S., late Dental Surgeon to the West London Hospital. Second Edition. With 78 Engravings. Fcap. 8vo, 5s. 6d.

STOCKEN.—**Elements of Dental Materia Medica** and Therapeutics, with Pharmacopœia. By JAMES STOCKEN, L.D.S.R.C.S., late Lecturer on Dental Materia Medica and Therapeutics and Dental Surgeon to the National Dental Hospital; assisted by THOMAS GADDES, L.D.S. Eng. and Edin. Third Edition. Fcap. 8vo, 7s. 6d.

TOMES (C. S.).—**Manual of Dental Anatomy,** Human and Comparative. By CHARLES S. TOMES, M.A., F.R.S. Second Edition. With 191 Engravings. Crown 8vo, 12s. 6d.

TOMES (J. and C. S.).—**A Manual of Dental** Surgery. By JOHN TOMES, M.R.C.S., F.R.S., and CHARLES S. TOMES, M.A., M.R.C.S., F.R.S.; Lecturer on Anatomy and Physiology at the Dental Hospital of London. Third Edition. With many Engravings, Crown 8vo. [*In the press.*

EAR, DISEASES OF.

BURNETT.—**The Ear: its Anatomy, Physio-** logy, and Diseases. A Practical Treatise for the Use of Medical Students and Practitioners. By CHARLES H. BURNETT, M.D., Aural Surgeon to the Presbyterian Hospital, Philadelphia. Second Edition. With 107 Engravings. 8vo, 18s.

DALBY.—**On Diseases and Injuries of the Ear.** By WILLIAM B. DALBY, F.R.C.S., Aural Surgeon to, and Lecturer on Aural Surgery at, St. George's Hospital. Third Edition. With Engravings. Crown 8vo. 7s. 6d.

EAR, DISEASES OF—*continued.*

JONES.—**A Practical Treatise on Aural Surgery.** By H. MACNAUGHTON JONES, M.D., Professor of the Queen's University in Ireland, late Surgeon to the Cork Ophthalmic and Aural Hospital. Second Edition. With 63 Engravings. Crown 8vo, 8s. 6d.

By the same Author.

Atlas of the Diseases of the Membrana Tympani. In Coloured Plates, containing 59 Figures. With Explanatory Text. Crown 4to, 21s.

FORENSIC MEDICINE.

ABERCROMBIE. — **The Student's Guide to Medical Jurisprudence.** By JOHN ABERCROMBIE, M.D., Senior Assistant to, and Lecturer on Forensic Medicine at, Charing Cross Hospital. Fcap 8vo, 7s. 6d.

OGSTON.—**Lectures on Medical Jurisprudence.** By FRANCIS OGSTON, M.D., late Professor of Medical Jurisprudence and Medical Logic in the University of Aberdeen. Edited by FRANCIS OGSTON, Jun., M.D., late Lecturer on Practical Toxicology in the University of Aberdeen. With 12 Plates. 8vo, 18s.

TAYLOR.—**The Principles and Practice of Medical Jurisprudence.** By ALFRED S. TAYLOR, M.D., F.R.S. Third Edition, revised by THOMAS STEVENSON, M.D., F.R.C.P., Lecturer on Chemistry and Medical Jurisprudence at Guy's Hospital; Examiner in Chemistry at the Royal College of Physicians; Official Analyst to the Home Office. With 188 Engravings. 2 Vols. 8vo, 31s. 6d.

By the same Author.

A Manual of Medical Jurisprudence. Tenth Edition. With 55 Engravings. Crown 8vo, 14s.

ALSO,

On Poisons, in relation to Medical Jurisprudence and Medicine. Third Edition. With 104 Engravings. Crown 8vo, 16s.

TIDY AND WOODMAN.—**A Handy-Book of Forensic Medicine and Toxicology.** By C. MEYMOTT TIDY, M.B.; and W. BATHURST WOODMAN, M.D., F.R.C.P. With 8 Lithographic Plates and 116 Wood Engravings. 8vo, 31s. 6d.

HYGIENE.

PARKES.—A Manual of Practical Hygiene. By EDMUND A. PARKES, M.D., F.R.S. Sixth Edition by F. DE CHAUMONT, M.D., F.R.S., Professor of Military Hygiene in the Army Medical School. With 9 Plates and 103 Engravings. 8vo, 18s.

WILSON.—A Handbook of Hygiene and Sanitary Science. By GEORGE WILSON, M.A., M.D., F.R.S.E., Medical Officer of Health for Mid Warwickshire. Fifth Edition. With Engravings. Crown 8vo, 10s. 6d.

MATERIA MEDICA AND THERAPEUTICS.

BINZ AND SPARKS.—The Elements of Therapeutics; a Clinical Guide to the Action of Medicines. By C. BINZ, M.D., Professor of Pharmacology in the University of Bonn. Translated and Edited with Additions, in conformity with the British and American Pharmacopœias, by EDWARD I. SPARKS, M.A., M.B., F.R.C.P. Lond. Crown 8vo, 8s. 6d.

LESCHER.—Recent Materia Medica. Notes on their Origin and Therapeutics. By F. HARWOOD LESCHER, F.C.S., Pereira Medallist. Second Edition. 8vo, 2s. 6d.

OWEN.—A Manual of Materia Medica; incorporating the Author's "Tables of Materia Medica." By ISAMBARD OWEN, M.D., F.R.C.P., Lecturer on Materia Medica and Therapeutics to St. George's Hospital. Crown 8vo, 6s.

ROYLE AND HARLEY.—A Manual of Materia Medica and Therapeutics. By J. FORBES ROYLE, M.D., F.R.S., and JOHN HARLEY, M.D., F.R.C.P., Physician to, and Joint Lecturer on Clinical Medicine at, St. Thomas's Hospital. Sixth Edition. With 139 Engravings. Crown 8vo, 15s.

THOROWGOOD.—The Student's Guide to Materia Medica and Therapeutics. By JOHN C. THOROWGOOD, M.D., F.R.C.P., Lecturer on Materia Medica at the Middlesex Hospital. Second Edition. With Engravings. Fcap. 8vo, 7s.

WARING.—A Manual of Practical Therapeutics. By EDWARD J. WARING, C.I.E., M.D., F.R.C.P. Fourth Edition. Crown 8vo. [*In the press*

MEDICINE.

BARCLAY.—**A Manual of Medical Diagnosis.** By A. WHYTE BARCLAY, M.D., F.R.C.P., late Physician to, and Lecturer on Medicine at, St. George's Hospital. Third Edition. Fcap. 8vo, 10s. 6d.

CHARTERIS.—**The Student's Guide to the Practice of Medicine.** By MATTHEW CHARTERIS, M.D., Professor of Materia Medica, University of Glasgow; Physician to the Royal Infirmary. With Engravings on Copper and Wood. Fourth Edition. Fcap. 8vo. [*In October.*

FAGGE.—**The Principles and Practice of Medicine.** By the late C. HILTON FAGGE, M.D., F.R.C.P., Edited by P. H. PYE-SMITH, M.D., F.R.C.P., Physician to, and Lecturer on Medicine at, Guy's Hospital. 2 Vols. 8vo. [*In October.*

FENWICK.—**The Student's Guide to Medical Diagnosis.** By SAMUEL FENWICK, M.D., F.R.C.P., Physician to the London Hospital. Fifth Edition. With 111 Engravings. Fcap. 8vo, 7s.

By the same Author.

The Student's Outlines of Medical Treatment. Second Edition. Fcap. 8vo, 7s.

FLINT.—**Clinical Medicine: a Systematic Treatise on the Diagnosis and Treatment of Disease.** By AUSTIN FLINT, M.D., Professor of the Principles and Practice of Medicine, &c., in Bellevue Hospital Medical College. 8vo, 20s.

WARNER.—**The Student's Guide to Clinical Medicine and Case-Taking.** By FRANCIS WARNER, M.D., F.R.C.P., Assistant-Physician to the London Hospital. Second Edition. Fcap. 8vo, 5s.

WEST.—**How to Examine the Chest: being a Practical Guide for the Use of Students.** By SAMUEL WEST, M.D., F.R.C.P., Physician to the City of London Hospital for Diseases of the Chest, &c. With 42 Engravings. Fcap. 8vo, 5s.

WHITTAKER.—**Student's Primer on the Urine.** By J. TRAVIS WHITTAKER, M.D., Clinical Demonstrator at the Royal Infirmary, Glasgow. With Illustrations, and 16 Plates etched on Copper. Post 8vo, 4s. 6d.

MIDWIFERY.

BARNES.—**Lectures on Obstetric Operations,** including the Treatment of Hæmorrhage, and forming a Guide to the Management of Difficult Labour. By ROBERT BARNES, M.D., F.R.C.P., Obstetric Physician to, and Lecturer on Diseases of Women, &c., at, St. George's Hospital. Third Edition. With 124 Engravings. 8vo, 18s.

BURTON.—**Handbook of Midwifery for Midwives.** By JOHN E. BURTON, M.R.C.S., L.R.C.P., Surgeon to the Liverpool Hospital for Women. Second Edition. With Engravings. Fcap 8vo, 6s.

RAMSBOTHAM.—**The Principles and Practice** of Obstetric Medicine and Surgery. By FRANCIS H. RAMSBOTHAM, M.D., formerly Obstetric Physician to the London Hospital. Fifth Edition. With 120 Plates, forming one thick handsome volume. 8vo, 22s.

REYNOLDS.—**Notes on Midwifery: specially** designed to assist the Student in preparing for Examination. By J. J. REYNOLDS, L.R.C.P., M.R.C.S. Fcap. 8vo, 4s.

ROBERTS.—**The Student's Guide to the Practice** of Midwifery. By D. LLOYD ROBERTS, M.D., F.R.C.P., Lecturer on Clinical Midwifery and Diseases of Women at Owen's College, Physician to St. Mary's Hospital, Manchester. Third Edition. With 2 Coloured Plates and 127 Engravings. Fcap. 8vo, 7s. 6d.

SCHROEDER.—**A Manual of Midwifery; including** the Pathology of Pregnancy and the Puerperal State. By KARL SCHROEDER, M.D., Professor of Midwifery in the University of Erlangen. Translated by CHARLES H. CARTER, M.D. With Engravings. 8vo, 12s. 6d.

SWAYNE.—**Obstetric Aphorisms for the Use of** Students commencing Midwifery Practice. By JOSEPH G. SWAYNE, M.D., Lecturer on Midwifery at the Bristol School of Medicine. Eighth Edition. With Engravings. Fcap. 8vo, 3s. 6d.

MICROSCOPY.

CARPENTER.—**The Microscope and its Revelations.** By WILLIAM B. CARPENTER, C.B., M.D., F.R.S. Sixth Edition. With 26 Plates, a Coloured Frontispiece, and more than 500 Engravings. Crown 8vo, 16s.

MICROSCOPY—*continued.*

LEE. — **The Microtomist's Vade-Mecum; a** Handbook of the Methods of Microscopic Anatomy. By ARTHUR BOLLES LEE. Crown 8vo, 8s. 6d.

MARSH. — **Microscopical Section-Cutting: a** Practical Guide to the Preparation and Mounting of Sections for the Microscope, special prominence being given to the subject of Animal Sections. By Dr. SYLVESTER MARSH. Second Edition. With 17 Engravings. Fcap. 8vo, 3s. 6d.

MARTIN.—**A Manual of Microscopic Mounting.** By JOHN H. MARTIN, Member of the Society of Public Analysis, &c. Second Edition. With several Plates and 144 Engravings. 8vo, 7s. 6d.

OPHTHALMOLOGY.

HARTRIDGE.—**The Refraction of the Eye. By** GUSTAVUS HARTRIDGE, F.R.C.S., Assistant Surgeon to the Royal Westminster Ophthalmic Hospital. With 87 Illustrations, Test Types, &c. Crown 8vo, 5s.

HIGGENS.—**Hints on Ophthalmic Out-Patient** Practice. By CHARLES HIGGENS, F.R.C.S., Ophthalmic Surgeon to, and Lecturer on Ophthalmology at, Guy's Hospital. Second Edition. Fcap. 8vo, 3s.

JONES.—**A Manual of the Principles and** Practice of Ophthalmic Medicine and Surgery. By T. WHARTON JONES, F.R.C.S., F.R.S., late Ophthalmic Surgeon and Professor of Ophthalmology to University College Hospital. Third Edition. With 9 Coloured Plates and 173 Engravings. Fcap. 8vo, 12s. 6d.

MACNAMARA.—**A Manual of the Diseases of** the Eye. By CHARLES MACNAMARA, F.R.C.S., Surgeon to, and Lecturer on Surgery at, the Westminster Hospital. Fourth Edition. With 4 Coloured Plates and 66 Engravings. Crown 8vo, 10s. 6d.

NETTLESHIP.—**The Student's Guide to Diseases** of the Eye. By EDWARD NETTLESHIP, F.R.C.S., Ophthalmic Surgeon to, and Lecturer on Ophthalmic Surgery at, St. Thomas's Hospital. Third Edition. With 157 Engravings, and a Set of Coloured Papers illustrating Colour-blindness. Fcap. 8vo, 7s. 6d.

OPHTHALMOLOGY—*continued.*

TOSSWILL.—**Diseases and Injuries of the Eye** and Eyelids. By LOUIS H. TOSSWILL, B.A., M.B. Cantab., M.R.C.S. Surgeon to the West of England Eye Infirmary, Exeter. Fcap. 8vo. 2s. 6d.

WOLFE.—**On Diseases and Injuries of the Eye:** a Course of Systematic and Clinical Lectures to Students and Medical Practitioners. By J. R. WOLFE, M.D., F.R.C.S.E., Senior Surgeon to the Glasgow Ophthalmic Institution, Lecturer on Ophthalmic Medicine and Surgery in Anderson's College. With 10 Coloured Plates, and 120 Wood Engravings, 8vo, 21s.

PATHOLOGY.

JONES AND SIEVEKING.—**A Manual of Pathological Anatom** By C. HANDFIELD JONES, M.B., F.R.S., and EDWARD H. SIEVEKING M.D., F.R.C.P. Second Edition. Edited, with considerable enlargement, by J. F. PAYNE, M.B., Assistant-Physician and Lecturer on General Pathology at St. Thomas's Hospital. With 195 Engravings. Crown 8vo, 16s.

LANCEREAUX.—**Atlas of Pathological Anatomy.** By Dr. LANCEREAUX. Translated by W. S. GREENFIELD, M.D., Professor of Pathology in the University of Edinburgh. With 70 Coloured Plates. Imperial 8vo, £5 5s.

VIRCHOW.—**Post-Mortem Examinations:** a Description and Explanation of the Method of Performing them, with especial reference to Medico-Legal Practice. By Professor RUDOLPH VIRCHOW, Berlin Charité Hospital. Translated by Dr. T. B. SMITH. Second Edition, with 4 Plates. Fcap. 8vo, 3s. 6d.

PSYCHOLOGY.

BUCKNILL AND TUKE.—**A Manual of Psychological Medicine:** containing the Lunacy Laws, Nosology, Ætiology, Statistics, Description, Diagnosis, Pathology, and Treatment of Insanity, with an Appendix of Cases. By JOHN C. BUCKNILL, M.D., F.R.S., and D. HACK TUKE, M.D., F.R.C.P. Fourth Edition with 12 Plates (30 Figures). 8vo, 25s.

CLOUSTON.—**Clinical Lectures on Mental Diseases.** By THOMAS S. CLOUSTON, M.D., and F.R.C.P. Edin.; Lecturer on Mental Diseases in the University of Edinburgh. With 8 Plates (6 Coloured). Crown 8vo, 12s. 6d.